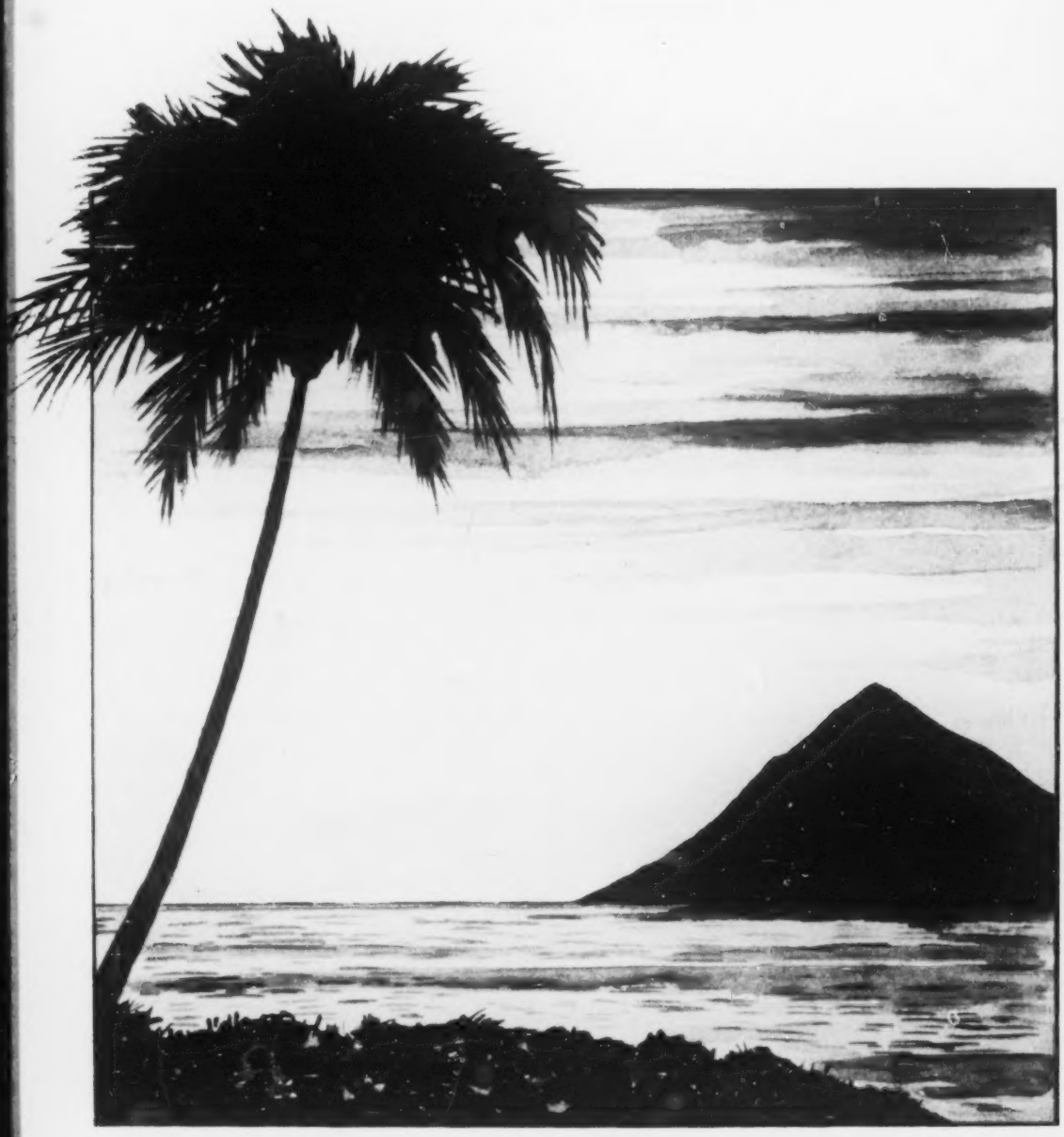
Integrated Renewable Resource Management for U.S. Insular Areas



Summary

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Washington, DC 20510-8025

J952-25

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Foreword

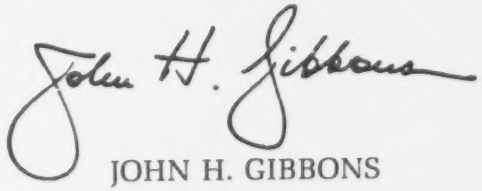
The United States has political, economic, humanitarian and strategic interests in sustained economic development of U.S.-affiliated Caribbean and Pacific islands. Despite a U.S. commitment to support the economic vitality of these islands, most have become *less* self-reliant in food and fiber production, and now depend increasingly on Federal funding for jobs, public welfare, and food and other goods and services to the islands.

Interest in the development of increased self-reliance in U.S.-affiliated islands has grown significantly in the last two decades. After 16 years of negotiation, the Congress, the United Nations and three governments emerging from the former Trust Territory of the Pacific Islands—the Republic of the Marshall Islands, the Federated States of Micronesia and the Commonwealth of the Northern Mariana Islands—approved agreements redefining their relationships with the United States. The remaining agreement, with the Republic of Palau, is expected soon, thus terminating the only remaining trusteeship created by the United Nations after World War II. Concomitant with the interest in development of island self-government has been concern over development of self-reliance. Similarly, the economic well-being of the U.S.-affiliated Caribbean islands has come under increasing scrutiny due to the growing strategic importance of the Caribbean Basin, and the implementation of the Caribbean Basin Initiative.

Several factors contributing to the growing dependence of U.S.-affiliated islands include: scant natural resources and long distances between islands and sources of inputs, products, or markets; rapidly growing populations; tropical resource characteristics with generally high natural productivity but extreme vulnerability to disruption; and common histories of significant resource degradation. Despite the latter, the economic constraints posed by size and isolation of many of these islands dictate that much of the productive sector be based on renewable resources—agriculture, aquaculture, fisheries, and tourism.

Renewable resource development can help foster self-sufficiency, but certain approaches are not compatible with sustained development (e.g., harvesting resources until long-term productivity is lost, resources are depleted, or the environment is degraded). Similarly, policies, programs, and projects that seriously conflict with local cultures and customs are likely to be counterproductive.

The Senate Committee on Energy and Natural Resources, in 1984, requested the Office of Technology Assessment to conduct an assessment of the constraints to development of insular resource-based enterprises, and the opportunities to improve sustainable renewable resource development and management on the U.S.-affiliated islands. The House Committee on Interior and Insular Affairs endorsed the request. The assessment identifies and discusses in-depth some constraints and opportunities to integrated management of renewable resources on these islands.



JOHN H. GIBBONS
Director

Integrated Renewable Resources Management for U.S. Insular Areas Advisory Panel

Fernando Abruna
Soil Scientist (retired)
Puerto Rico

John S. Corbin
Aquaculture Development Program
Hawaii Department of Land and Natural Resources

Eric Dillingham
Farmer
U.S. Virgin Islands

Lucius G. Eldredge
Micronesian Area Research Center
University of Guam

Sam Falanruw
Department of Resources and Development
Yap State Government

Michael J. Gawel
Chief of Marine Resources
Federated States of Micronesia

Michael Hamnett
Pacific Islands Development Program
East/West Center

Stanley Hosie
Foundation for the Peoples of the South Pacific

Carolyn Imamura
Planning and Programs
Pacific Basin Development Council

Robert E. Johannes
Division of Fisheries Research
CSIRO Marine Laboratories

Shelley M. Mark
Department of Agriculture and Resource Economics
University of Hawaii

John Matuszak
VI Cooperative Extension Service
College of the Virgin Islands

Jerome McElroy
Department of Business Administration and Economics
Saint Mary's College

Dieter Mueller-Dombois
Department of Botany
University of Hawaii

Robert Owen
Chief Conservation Officer (retired)
Trust Territory of the Pacific Islands

Maria T. Pangelinan
Saipan Farmers Cooperative Association

Frank Peterson
Department of Geology and Geophysics
University of Hawaii

Allen Putney
Eastern Caribbean Natural Areas Management Program
West Indies Lab

Ralph Schmidt
Forest Division
Food and Agriculture Organization
Rome, Italy

Ace Tago
Pacific Management and Research Associates

Edward Towle
Island Resources Foundation

Patrick Williams
Commissioner of Agriculture
U.S. Virgin Islands

Adrian Winkel
Former High Commissioner
Trust Territory of the Pacific Islands

NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the reviewers. The reviewers do not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

OTA Project Staff on Integrated Renewable Resource Management of U.S. Insular Areas

Roger Herdman, *Assistant Director, OTA*
Health and Life Sciences Division

Walter E. Parham, *Program Manager*
Food and Renewable Resources Program

Alison L. Hess, *Project Director*

Analytical Staff

Patricia J. Durana, *Research Analyst*[1]

David S. Liem, *Analyst*[2]

Eric Passaglia, *Special Assistant and Spanish Translator*[3]

Meriwether Wilson, *Research Analyst*[2]

Susan J. Wintsch, *Contracted Editor*

Benjamin Yarofmal, *Research Assistant*[4]

Clerical Staff

Patricia Durana[5] Rebecca Erickson[6] Sally Shafroth[7]
Administrative Assistants

Carolyn Swann Nellie Hammond
Secretaries

---

[1]From August 1985.
[2]From January 1985 to May 1985.
[3]From June 1985 to September 1985.
[4]From May 1986 to August 1986.
[5]From October 184 to August 1985.
[6]From August 1985 to November 1986.
[7]From November 1986.

Acknowledgments

OTA greatly appreciates the contributions of its advisory panel and workshop participants assembled for the study, and the authors of the commissioned papers. We are especially grateful for the time and effort donated by the numerous contributors who served as reviewers and as liaisons from the insular governments and other government agencies. In addition, we would like to thank those from within OTA who provided assistance, particularly Dr. Gordon Law of the International Security and Commerce Program. As with all OTA studies the content of the report is the sole responsibility of OTA.

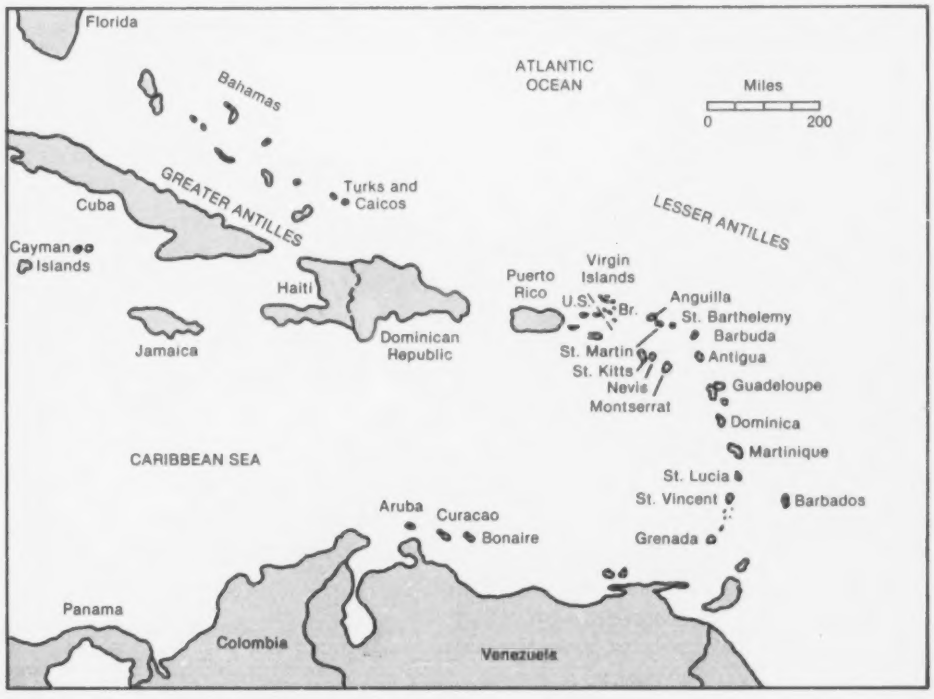
Integrated Renewable Resource Management for U.S. Insular Areas

INTRODUCTION

The U.S.-affiliated tropical islands include Puerto Rico and the U.S. Virgin Islands (USVI) in the Caribbean (figure 1) and American Samoa, Guam, the Commonwealth of the Northern Marianas Islands (CNMI), the Republic of the Marshall Islands (RMI), the Federated States of Micronesia (FSM), and the Republic of Palau in the Pacific (figure 2). All of these islands, except Puerto Rico, are very small (table 1); the Micronesian island groups are distributed over an area as large as the conterminous United States (figure 3) but have an aggregate land area less than that of Rhode Island. The U.S.-affiliated Pacific islands also are distant from major foreign population centers.

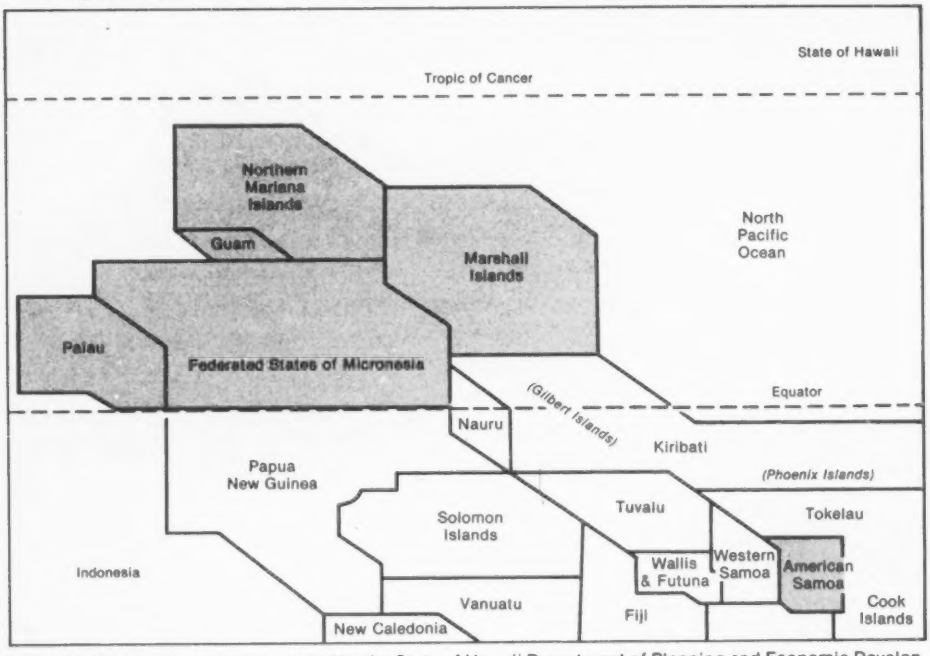
As commonwealths, Puerto Rico and the CNMI have autonomous governments, but are voluntarily associated with the United States. The USVI, American Samoa, and Guam are unincorporated territories with semi-autonomous governments and their own constitutions. The FSM

Figure 1.—U.S.-Affiliated Caribbean Islands and Neighboring States



SOURCE: Office of Technology Assessment, 1987.

Figure 2.—U.S.-Affiliated Pacific Islands and Neighboring States



SOURCE: Adapted from a map prepared by the State of Hawaii Department of Planning and Economic Development, 1984.

Table 1.—Population, Land Areas, and Estimated U.S. Federal Expenditures in U.S.-Affiliated Islands

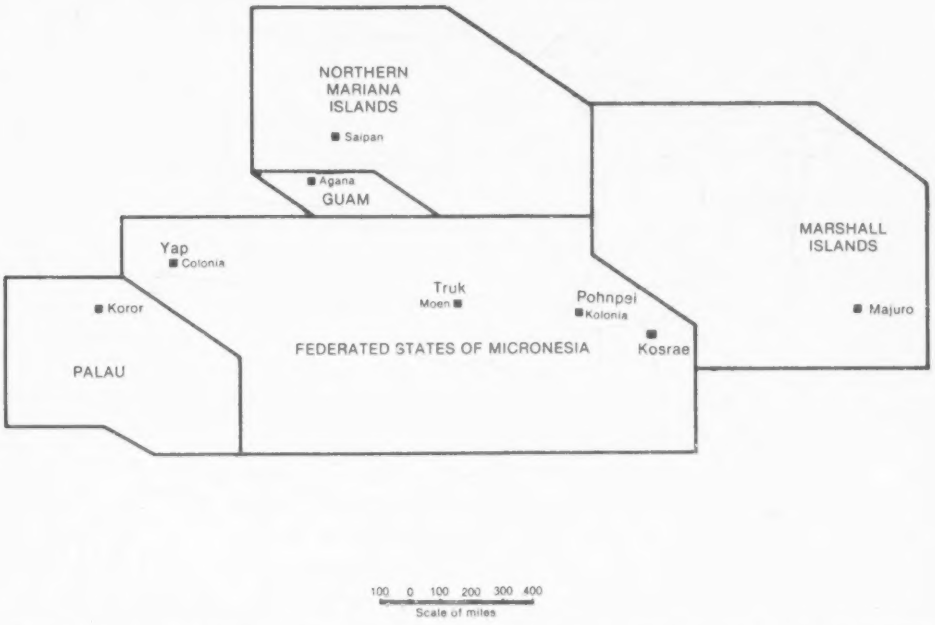
Insular area	1984 Population[a]	Land area (sq. mi.)[b]	Approximate number of islands	Estimated U.S. Federal expenditures, 1984[c]
Puerto Rico	3,270,000	3,425	4	$5,420 million
U.S. Virgin Islands	107,500	132	66	$ 387 million
Guam	119,800	209	1	$ 768 million
American Samoa	35,300	77	7	$ 61 million
Northern Mariana Islands	18,600	182	21	$ 103 million
Marshall Islands	34,900	70	1,225	
Federated States of Micronesia	88,400	279	607	$ 163 million
Palau	13,000	179	350	

SOURCES: [a] *Land Use Planning Report*, 13(46):365, November 25, 1985; U.S. Department of State, *1984 Trust Territory of the Pacific Islands*, report to the United Nations on administration of the Trust Territory of the Pacific Islands, 1985.

[b] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *Puerto Rico Coastal Management Program and Final Environmental Impact Statement* (Washington, DC: U.S. Department of Commerce, 1978); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *The Virgin Islands Coastal Management Program and Final Environmental Impact Statement* (Washington, DC: U.S. Department of Commerce, 1979); U.S. Department of State, *Annual Reports* for American Samoa, Guam, and the Trust Territory of the Pacific Islands, 1980.

[c] U.S. Department of Commerce, Bureau of the Census, *Federal Expenditures by State, FY 1985* (Washington, DC: U.S. Government Printing Office, 1986). Includes: 1) Grants to State and local governments, 2) Federal salaries, 3) payments to individuals, 4) procurement, and 5) other.

Figure 3.—Micronesia and the Contiguous United States: A Comparison of Size



SOURCE: Adapted from H.F. Nufer, *Micronesia Under American Rule: An Evaluation of the Strategic Trusteeship (1947-1977)* (Hicksville, NY: Exposition Press, 1978).

and RMI, which (along with the CNMI and Palau) comprised the former Trust Territory of the Pacific Islands, have recently signed compacts with the United States to become Freely Associated States. This status allows the islands free control of internal affairs, assures them fiscal aid, and makes them eligible for some international aid; the United States retains responsibility for national defense.

The majority of the U.S.-affiliated islands have developed dependence on Federal funding to provide jobs, to support public welfare, and to import food and other goods and services to the islands. Several factors common to the U.S.-affiliated islands have contributed to this dependence:

1. lack of full political status and benefits of States;
2. scant natural resources and large distances between islands and sources of inputs, products, or markets;
3. rapidly growing populations;
4. tropical resource characteristics with generally high natural productivity but extreme vulnerability to disruption; and
5. common histories of resource degradation.

Despite the United States' past and present commitment to the economic vitality of the U.S.-affiliated islands, most have become less self-sufficient in food production over the past several decades. This dependence amounts to a complete reversal of precontact tradition. Be-

fore European discovery, the inhabited Pacific and Caribbean islands were self-supporting. People subsisted on the available marine and terrestrial natural resources and extended family systems provided for members unable to provide for themselves.

Changes occurred with colonization and the increasing influence of foreign cultures. Colonial policies and practices over several centuries, the introduction of new fishery and agricultural technologies and cash economies, military occupation and use, and the advent of tourism, all have affected island resource systems and uses. Growing populations on many islands represent an added stress on an already limited resource base.

High levels of financial aid from the United States during the last two decades have not fulfilled the intention of fostering modern, self-sufficient island economies. Largely directed toward social support programs, generous aid packages may have reduced local incentives to pursue that goal.

A self-sufficient economy meets as many domestic needs as possible, and generates export revenue to pay for the imports required for a desired or acceptable standard of living. Development of an active productive sector on the islands may foster increased self-sufficiency. The economic constraints posed by size and isolation of many of these islands dictate that much of the productive sector be based on natural resources—e.g., agriculture, fisheries, and tourism.

Renewable resource development can help foster self-sufficiency, but sustainable development precludes certain approaches. For example, harvesting resources to the point where long-term productivity is lost, resources are depleted, or the environment is degraded is ultimately counterproductive. Similarly, policies, programs, and projects that seriously conflict with local cultures and customs are likely to be counterproductive.

Insular Resource History and Trends

Although the histories of the peoples and settlement of the U.S.-affiliated island areas are diverse, certain common factors exist:

1. on most islands, relatively large indigenous populations were sustained by island resources before western contact and remnants of traditional agriculture and fishery practices still exist on many islands;
2. all of these islands were colonized or administered by foreign nations whose activities primarily were designed to exploit island resources; and
3. all of the islands have been of some strategic importance to the United States and most remain so.

The islands share common renewable resource problems, including both natural (e.g., flooding, landslides, and other natural hazards) and manmade resource degradation. Deforestation and soil-moving for agriculture and construction have caused heavy soil erosion on many is-

lands and adversely affected the surrounding coral reefs. Numerous island species are near extinction, and others have already gone extinct, due partly to habitat loss (e.g., removal of mangroves), to overexploitation (e.g., hunting of fruit bats), and to introduction of exotic competitive or predatory species (e.g., brown tree snake, mongoose). Increasing human population density, combined with inadequate sewage treatment, and introduction of agricultural and industrial chemicals has reduced freshwater and nearshore water quality on many islands. Oil spills have damaged nearshore environments in both the Pacific and the Caribbean.

Turtles, nearshore fish and shellfish, and certain tree species have been overexploited in many island areas. Despite attempts to recover declining populations, poaching by local inhabitants and foreign nationals continues. Dynamite and chlorine bleach used by Pacific fishermen to "fish" have long-term destructive effects on the reef and lagoon areas. Dredging and mining in nearshore areas has resulted in the loss of many mangrove areas and coral reefs, which in turn may adversely affect nearshore fishery potential. Shipwrecks, heavy sedimentation, and anchor gouges have caused significant degradation of coral reefs and seagrass beds near many islands.

Puerto Rico's nearshore waters have been heavily exploited and very nearly overfished. Similarly, even modest increases in fishing effort could surpass the natural capacity of waters around the USVI. While good data on harvest levels and production capacities in the Pacific are lacking, there is evidence of depletion in the nearshore environment, particularly around urban centers.

More exotic resource problems remain in the Pacific islands. American and Japanese military ordnance from World War II still litter some of the islands, presenting a hazard to humans and inhibiting the use of some lands. Chemical repositories on Johnston Island have leaked military chemicals into the groundwater. Nuclear testing in the Marshalls has rendered several islands virtually uninhabitable. Efforts are being made to restore these islands to habitable conditions. Although surface nuclear tests have been banned; other islands still are used as nonnuclear practice bombardment targets.

Concerns have increased over adverse trends in resource use resulting in efforts to maintain or enhance resources on many of the U.S.-affiliated islands. These concerns have been expressed in a variety of ways, including:

- efforts to **maintain** the resource base (e.g., coastal resource management);
- efforts to **restore** the renewable resource base (e.g., reforestation, captive breeding of endangered populations);
- efforts to **redirect use** to underused resources (e.g., outer reef fisheries);
- efforts to **culture** species (e.g., aquaculture, culture of crops currently gathered from the wild); and
- efforts to **enhance** existing renewable resources (e.g., artificial reefs, enrichment planting of forests).

Sustainable renewable resource management depends not only on the capability of the ecological resources, but also on the availability of skilled labor and willingness to engage in resource management and development activities. Many young adults seek education and employment opportunities in the U.S. mainland. Despite substantial outward migration, remaining populations are rapidly growing.

Many of those who remain depend on extended family relationships and social support programs to supply their needs. Most formal labor is captured by local governments and services for the public sector and its employees. Wages, security, and prestige are higher in government employment. Skilled labor, training, and interest in the agriculture and fisheries sectors are low on all the islands.

Insular Renewable Resources

Characteristics of island resources—soil, water, vegetation, and wildlife—determine the uses and technologies that may be implemented productively and sustainably. U.S.-affiliated islands may be categorized into four groups with common resource characteristics:

1. **high volcanic islands:** peaks of undersea volcanoes (both active and dormant), often surrounded by fringing reefs;
2. **low-lying atolls:** composed entirely of coral-line reef limestone enclosing a lagoon;
3. **raised limestone islands:** primarily limestone, originally formed in waters surrounding older volcanic islands and is now above sea level; and

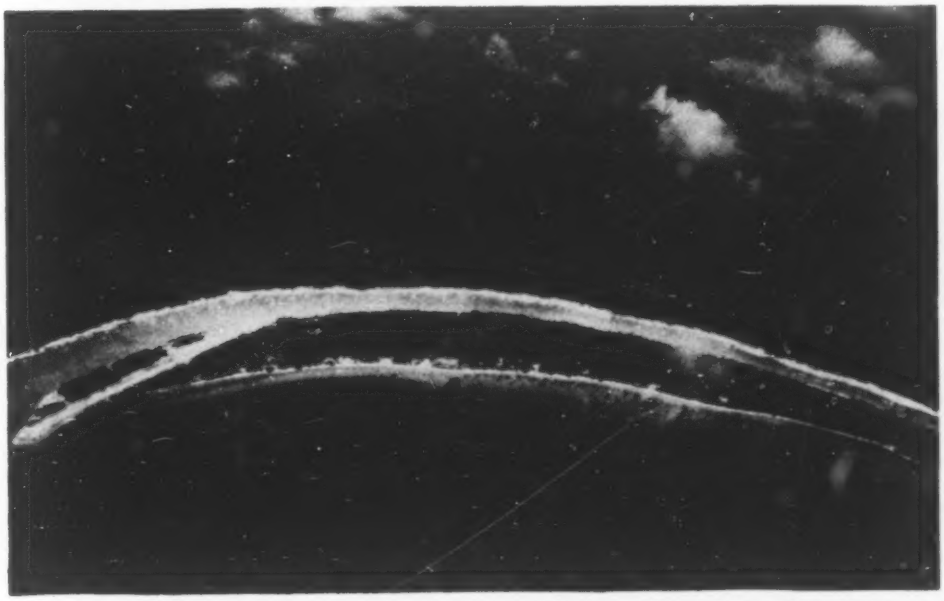


Photo credit: Office of Technology Assessment

A low-lying atoll island in the Marshall Islands, built on the inside edge of an encircling coral reef.

4. **continental islands:** geologic extensions of continents or parts of certain undersea mountain ranges.

All of the islands are within the tropical climatic region characterized by warm, relatively stable temperatures and commonly high humidity. Precipitation levels vary widely among the islands. Rainfall has high kinetic energy and, thus, greater ability to erode soils than in temperate regions. Further, the islands are vulnerable to major disturbances—hurricanes and typhoons (e.g., the western north Pacific receives an average of 26.3 typhoons per year), which can have devastating effects on resources, infrastructure, and populations.

Freshwater availability is determined largely by island structure. Atolls have no natural surface water and retain little groundwater due to highly permeable soils. On the other hand, flash flooding and heavy erosion is common on high islands where slopes are steep. Hydrologic systems are much more complex on continental islands, corresponding to their more complex geology.

Chemical weathering of soils predominates on tropical islands causing accelerated leaching of soil nutrients. Resultant soils generally are nutrient-poor regardless of parent rock type. Further, the chemical composition of the resulting soils often is imbalanced so that many food or tree crops will exhibit stunted growth or will not survive.

Because of differing histories of formation and geology, the nature and extent of renewable resources on the islands vary. However, their insular ecology leads to certain commonalities among resource systems:

- richness in endemic species,

Photo credit: B.C. Stone for National Academy of Sciences

Although once completely forest-covered, 50,000 acres of open or grass-covered land on Guam are infertile, barren, and actively eroding.

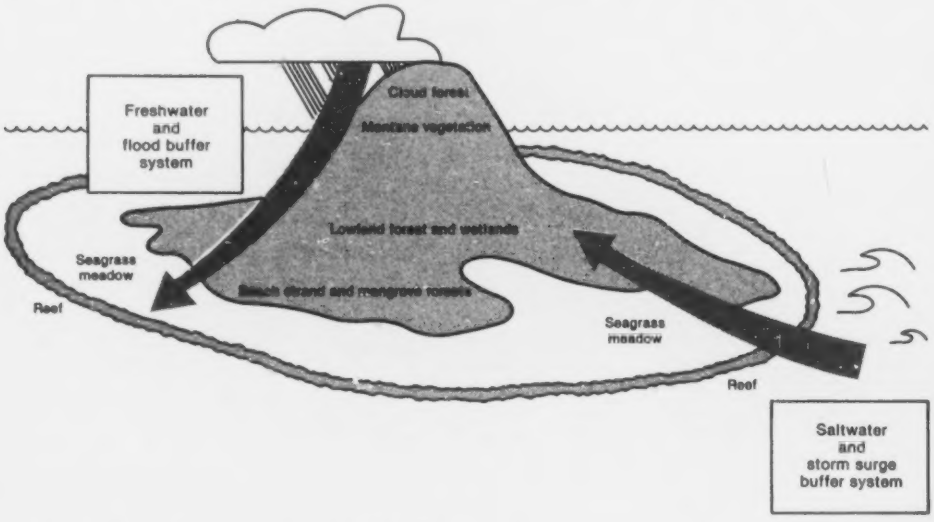
- species-richness of forests,
- value to science disproportionate to their size,
- vulnerability to disruption, and
- vulnerability to overexploitation.

Islands as Integrated Resource Systems

Island ecosystems are closely interrelated. Island terrestrial ecosystems, structured topographically from highland forests to coastal vegetation, sequentially buffer the erosive forces of heavy tropical rainfall and rapid runoff and protect nearshore marine ecosystems from excessive freshwater intrusion and sedimentation (figure 4). Similarly, the combination of coral reefs, seagrass beds, and littoral vegetation serve to reduce the erosive energy of wave action, thereby protecting shorelines from erosion and providing the basic conditions for island expansion. Organic matter also is transported among these ecosystems via water flow and movement of animals, allowing recolonization and recovery of degraded areas. Thus, the value of individual ecosystems includes not only the particular resources they contain, but also their essential functions in the insular ecology.

Unmodified island ecosystems generally are at equilibrium. However, environmental manipulation or modification generally is necessary to accommodate human populations. If such modifications allow the natural flow of energy, freshwater, and nutrients through the system the natural equilibrium still may be maintained. Options exist in the methods and types of modifications to be enacted; selection of a development approach which mimics or acts in concert with the desired natural process will result in fewer impacts on associated ecosystems.

Figure 4.—Erosive Energy Buffer Systems on Islands



SOURCE: Office of Technology Assessment, 1986.

Traditional island societies demonstrated a keen sense of the interrelated nature of the island ecosystems: activities were designed to mimic natural ecosystems and preserve related environmental functions. Damaged areas were left fallow allowing natural recovery processes to restore productivity. Present population pressure coupled with human economic desires preclude most resource uses which rely on time for recovery. Alternative methods include abandoning degraded lands, or expending considerable money, energy, and effort to reclaim sites (e.g., reforestation).

The U.S.-affiliated islands' renewable resources still provide many goods and services, however, they have not become the basis of viable, modern economies. A variety of factors constrain efforts to achieve this goal.

Constraints to the Sustainable Development of Renewable Resources

A number of physical, biological, geographical, and socioeconomic factors constrain sustainable renewable resource development and management on U.S.-affiliated islands. Physical constraints that particularly affect small island agriculture and land-based aquaculture are limited availability of land and water resources. Low fertility of tropical soils, occasional torrential rainfall, distinct dry seasons on some islands, and mountainous topography of high volcanic and continental islands may preclude some types of agricultural activity. Physical constraints to fisheries development include low productivity of offshore tropical waters and limited extent of productive nearshore areas. Many nearshore resources already are being exploited near or beyond sustainable levels. Marine ecosystems are extremely vulnerable to natural and human disturbance, often requiring long recovery periods.

Added to these constraints are the lack of reliable data on the status of island terrestrial and marine renewable resources, and incomplete understanding of the "mechanics" of tropical ecosystems. The development strategies and technologies designed for temperate fisheries and agriculture are not readily transferable to tropical settings. Failure to appreciate this may explain why many "western" attempts to manage and develop resources in tropical settings generally have not been successful.

Geographically, the Pacific islands are extremely isolated. Transportation in general is difficult and unreliable. These factors, combined with small size or lack of formal markets for export products, and proximity of major Asian competitors, make it difficult or impossible to achieve economies of scale. Such constraints are much less severe in the Caribbean.

Sustainable resource development is limited not only by the inherent nature of tropical resources, and island geographic settings, but also by several socioeconomic characteristics of the islands. In the Pacific, certain resource ownership and use traditions constrain access to resources by "outsiders," including other islanders, who may be inter-

ested in developing the resource. Commercial development of resources, in particular, is contrary to traditions of harvesting for immediate subsistence use only, and of sharing any harvesting excess with needy relatives or friends.

The skills and knowledge needed for sustainable resource development is also scarce on these islands. Environment and resources play a minor role in school curricula, or are entirely neglected. Education at all levels is primarily oriented toward liberal arts. A preference exists for government employment rather than in the fisheries and agriculture sectors which are perceived as "lower status." Many who do not find government jobs, migrate to the mainland United States, and many who leave the islands to pursue higher education never return. Outmigration and reluctance of the islanders to work in some types of employment creates a demand for alien immigrant workers, whose presence may create social tensions.

Opportunities for the Sustainable Development and Use of Renewable Resources

Opportunities exist for expanding the role of renewable resources in the economic development of the islands, and for reducing the islands' heavy dependence on imports and U.S. aid.

Warm temperatures and generally favorable climates characterize most of the U.S.-affiliated islands in both the Pacific and Caribbean regions. The islands are capable of sustaining high agricultural and aquatic productivity. The mangrove, seagrass, and coral reef ecosystems of these islands are highly productive and rich, and interactively support populations of economically valuable marine organisms.

Nearshore marine resources show signs of stress in both regions. However, the success of the Japanese in Micronesia during the mandate period suggests there is unrealized potential in the Pacific for marine resource development, particularly through expanded use of underexploited and migratory species. Aquaculture may have some potential in the U.S.-affiliated islands to supply both local and export markets. Both regions have appropriate sites for pond, estuarine, or offshore culture systems. However, significant constraints to aquaculture development exist, including high cost of inputs, difficulty in obtaining juveniles, and lack of aquaculture extension services. Thus, aquaculture has not been developed to any great degree in the U.S.-affiliated islands.

The high islands of the Pacific and Puerto Rico also have significant terrestrial resources. There is potential for making traditional agricultural methods more productive and for introducing new crops and technologies to the U.S.-affiliated islands. Agroforestry, a landuse system that integrates or rotates growth of woody perennials and nonwoody crops or animals was traditionally practiced on many U.S.-affiliated islands. Incorporating trees into more productive agricultural systems can optimize landuse while retaining the advantages of a forest (watershed protection, erosion control, wildlife habitat).

Commercial agriculture still is considered desirable for the U.S.-affiliated islands. Even small islands may become successful producers of specialty crops attractive to world markets. Pohnpei black pepper, for example, has penetrated U.S. gourmet markets. Coffee, nuts, spices, essential and perfume oils, cacao, and certain ornamental plants, fruits, and vegetables are all high-value crops which have market potential.

The natural resources of tropical islands also may contribute to economic development through tourism. Tourists are attracted to the islands because of their warm climates, coral reefs, beaches, flora and fauna, and spectacular scenery. Tourism and related industries currently comprise the major economic sector of the USVI, and tourist presence in the Pacific region is growing rapidly. Tourists provide revenue by purchasing food, services, and island handicrafts. Although tourism has created environmental and social problems in the past, it has the potential to contribute significantly to the economic self-sufficiency of the U.S.-affiliated islands. Ideally, the tourism industry would be planned and developed to maximize economic benefits to the islanders and minimize negative environmental and social impacts.

Successful and sustainable renewable resource development may assist in increasing the self-sufficiency of the U.S.-affiliated islands. There are many other potential benefits, including reduced unemployment

Photo credit: Office of Technology Assessment

Growing numbers of tourists visit the U.S.-affiliated tropical islands to enjoy their natural beauty and explore cultural and historic sites. (Pictured here Truk Lagoon.)

and outmigration, improved lifestyles for islanders, and maintenance of biological diversity. If development is sensitive to island traditions and practices, it can also contribute to the retention of rich cultural heritages.

DEVELOPMENT GOALS AND STRATEGIES

Introduction

Imports constitute the bulk of island consumption, thus, to increase self-sufficiency territories must either produce enough to satisfy local consumption, or generate export earnings to balance imports, or both. In view of the constraints to agricultural development and increasing depletion of nearshore marine resources on many islands, total self-sufficiency is probably not attainable. A more attainable goal may be to improve the islands' long-term productive capacities through optimal use of land available for food production (taking into account other land use requirements), redirection of marine harvest to include certain underexploited species and offshore areas, and further development of culture techniques. Strategies for agriculture or fisheries development could be tailored to nonmarket, semicommercial or full commercial production as appropriate. What is appropriate may vary among islands and will depend on many geographical, ecological, and socioeconomic factors.

The integrated management of renewable resources for sustained yields requires a blend of strategies for resource development as well as for resource conservation, recovery, and replenishment. Strategies simply to increase harvests of already overexploited resources may raise yields initially, but will ultimately lead to depletion that may be irreversible.

Agriculture, Agroforestry, and Forestry

Traditional forms of agriculture remain on many islands, especially in the Pacific. These forms evolved to be productive while retaining many natural ecosystem functions. Common Pacific island systems are:

- culture of wetland taro,
- atoll pit taro culture,
- mixed "tree gardening,"
- intermittent tree gardening,
- "lanchos" (weekend farms) and backyard gardening, and
- traditional open canopy culture.

In the U.S. Caribbean, little indigenous agriculture remains, but traditional agriculture systems have been brought into Puerto Rico and the USVI by "down-island" migrants such as the French herb farmers from neighboring St. Barthelemy who practice a specialized form of polyculture of herb and tree crops.

Despite the success of traditional systems, most modern attempts to develop agriculture on the islands largely have followed the U.S. exam-

Photo credit: C. Hodges

Eighty percent of American Samoan households engage in small-scale agriculture, commonly an indigenous polyculture as pictured here.

ple of consolidated, capital-intensive monocultures requiring imported fertilizers, pesticides, irrigation or drainage systems, and mechanization. Although efforts to develop agriculture in the U.S.-affiliated Pacific islands have been introduced as small-scale projects for limited-resource farmers, many have been unsuccessful for reasons including:

- lack of markets,
- low market prices,
- technologies dependent on imported inputs,
- lack of management skills among farmers,
- diseases and pests, and
- a general lack of commitment by the U.S. and local governments.

Agriculture in the U.S.-affiliated Caribbean islands historically centered around major export crops including such commodities as sugar, tobacco, and coffee. Most of this type of agriculture was abandoned as markets declined and soils became degraded. Development of modern agriculture in the U.S. Caribbean has seen some success, especially in dairy and beef production, and vegetables and fruits. Still, Puerto Rico annually imports about 1.2 billion dollars' worth of food. Most farm operators in the USVI and Puerto Rico also engage in off-farm wage-earning activities. Many lands have been abandoned, and agriculture has adapted to resource loss by reducing farm size and effort, replacing capital-intensive inputs, and changing the composition of output from export crops to domestically consumed products.

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Major constraints to agricultural development which apply to all of the U.S.-affiliated islands generally fall into the following categories: biophysical, economic, infrastructural, and sociocultural. Major biophysical constraints are low soil fertility, limited or irregular water resources, and limited arable land of suitable soil types and level topography. Land tenure systems, characterized by fragmented landholdings and clan influence over use rights, are primary cultural constraints. Economic constraints include the small size of domestic markets for agricultural products, availability of high-paying alternate employment, low social esteem of farming, high cost of imported livestock feed and other inputs, and in tourism-dominated islands, the relatively low value of agricultural lands compared to other uses (i.e., commercial real estate). Undeveloped infrastructure on some islands (i.e., lack of rural farm roads, scarcity of transportation to markets) also pose constraints.

Successful tropical island agricultural systems generally exhibit characteristics which mimic and extend natural ecosystem processes by providing for water and nutrient flow, and maintaining a canopy to protect and enhance soil quality at critical periods. An agricultural system which incorporates a diversity of crop species and varieties strengthens the system's resilience to disruption from pests and disease outbreaks and, further, provides a variety of products throughout the year despite erratic weather patterns. For such systems to be readily adopted, they should be based on traditionally used systems and require minimal exotic, nonrenewable inputs such as fossil fuel energy or derived chemicals.

Major characteristics of ecologically and economically sustainable systems include:

- mimicking natural systems through polycultures that incorporate perennial species,
- optimization of agroecosystem components (e.g., maximizing recycling of locally available plant nutrients and natural maintenance of soil moisture) rather than maximization of total yield,
- provision of farmer and consumer security in areas prone to natural disaster and in areas with small and erratic markets, and
- emphasizing incremental changes from traditional agricultural systems to ease and speed adoption.

Although farm size, type of technologies applied, and farming goals are not directly related, agriculture in the U.S.-affiliated islands can be classified into four general types that comprise a continuum of farming systems:

1. **Subsistence smallholder:** Family (or clan) member(s) producing solely for family consumption, although "surplus" commodities may be sold. Traditional cropping or gathering techniques commonly are used, and the number of crops produced usually is greater than in commercial smallholder systems.
2. **Semicommercial smallholder:** Individual or family members regularly producing commodities for the market, but only on a part-time basis. Farming may or may not be regularly directed to home

consumption (the farmer may have a full-time wage job in the money economy). Commodities sometimes are produced using modern technology.

3. **Commercial smallholder:** Individual or family member(s) producing solely or substantially for the market. Commercial smallholders typically are full-time producers who derive their principal livelihood from farming. Commodities are normally produced using modern technology. The range of crops is much narrower than for the subsistence smallholder. The commercial smallholder may have a few wage employees, but most would rely solely on unpaid family labor.
4. **Large-scale commercial farming:** Usually would be characterized by significant investment in operation, and use of paid wage and salary workers. Ownership commonly would be corporate in form, with production using modern, high-input technology. Output per unit of land or labor would tend to be much higher than for smallholder agriculture.

"Large-scale" commercial farming on the islands is not large by continental U.S. standards. Commonly, field farming of over 20 acres or annual gross sales over $20,000 is considered a large-scale operation for the U.S.-affiliated islands. Most farming in the U.S. Pacific is subsistence and semicommercial; in the U.S. Caribbean islands, small-scale commercial and semicommercial farming is prevalent. In Puerto Rico, several large-scale enterprises exist, but the most recent of these (a large rice project on the north coast and one Israeli-sponsored vegetable and fruit development on the south coast) have failed. For the most part, island ecologies and economies are not conducive to large-scale farming.

Strategy: Support and Protect Nonmarket Agriculture

Nonmarket (subsistence and part-time) agriculture provides the basis for good nutrition and a cadre of people who will retain the interests and skills allowing future upgrading to semicommercial and commercial systems.

Most subsistence agricultural systems are characterized by high crop diversity, are well adapted to natural conditions, are strongly rooted in local culture, and make maximum use of local resources. These systems generally are stable, sustainable, and ecologically benign. They often provide beneficial environmental services, such as soil stabilization and habitat protection.

Without a conscious effort to preserve such food production systems, even relatively stable systems may become rare or disappear along with the rich genetic heritage they represent. Most traditional systems already are declining. Potential mechanisms to support nonmarket agriculture include:

- consideration of the impacts of development on traditional agriculture (e.g., as a component of environmental impact statements);
- provision of research and extension services for backyard gardeners; and

- enhanced game management to protect traditional agriculture and provide an alternate source of protein for low-income families.

Development projects that might have adverse impacts on traditional agricultural systems could be redesigned.

Strategy: Develop Smallholder Agriculture

Development of smallholder agriculture could generate cash income for subsistence farmers in the Pacific, and increase income for small-scale or semicommercial farmers in both the Pacific and Caribbean areas. Modest acreage is required for smallholder operations, which rely heavily on family labor. Policies and technologies which would raise subsistence sector productivity and strengthen urban markets for local farm products could assist in gradually expanding nonmarket production to semicommercial production.

Several common characteristics of traditional systems might be integrated with modern practices to achieve more productive agricultural systems with commercial potential. Improved cultivars of traditional crops, as well as the introduction of new crops and technologies may be appropriate for development efforts. Trees could be incorporated with crops in new, more productive versions of traditional agroforests, space would be used as efficiently as possible, and crop combinations designed to maximize overall productivity on a sustainable basis. Similarly, livestock could be penned and fed agricultural wastes, thus providing a supplementary protein or income source and a supply of organic matter to re-apply to fields.

Commercial small-scale operations may be handicapped by small and unstable markets or inadequate transportation services. Moreover, small

Photo credits: Office of Technology Assessment

This semicommercial mixed polyculture on St. Thomas,USVI, provides more than 30 crops for the farmer's subsistence and for sale in a roadside stand.

This commercial enterprise in Puerto Rico employs drip irrigation and modern nursery techniques to cultivate coriander, a high-value specialty crop.

producers commonly are not able to produce uniform quality products, do not have access to adequate capital, and lack marketing skills. Thus, development of small-scale farming systems probably would require strong government and private sector support for credit, identification and extension of appropriate technologies and crops, and identification and creation of market outlets.

Development of smallholder agriculture is likely to benefit the large number of subsistence farmers (Freely Associated States), semicommercial, and part-time farmers (American Samoa, Guam, the CNMI, Puerto Rico, and the USVI) in the U.S.-affiliated islands. Further, it is likely to be more compatible with the present land tenure systems than would large-scale farming. Smallholders tend to produce a large range of commodities which may alleviate marketing constraints in small size markets.

Strategy: Develop Intensive Commercial Farming

Although subsistence and semicommercial farms may satisfy many local food needs, additional commercial and competitive operations are needed to generate cash to pay for imports. The high input requirements of large-scale commercial agriculture limit its applicability on most of the U.S.-affiliated islands. Large parcels of land with uniform soil types are scarce in the Pacific territories; where they occur in the Caribbean, they are expensive. Local markets to absorb large product volumes are also lacking, export potential is difficult to achieve, and transportation is poor. Although these factors all constrain the development of large-scale commercial farming, particularly in the Pacific, selective opportunities for such development exist. On Puerto Rico some large-scale farming is possible. New technologies, including drip irrigation and improved pasture technologies, may be needed to increase productivity and raise the quality of crops and livestock with large-scale commercial potential. In some cases, improvements in management alone may increase yields.

Highly productive, commercial agriculture could be developed on a smaller scale in other island areas. Certain carefully selected crops and modern technologies could be adapted to tropical island ecology. Where appropriate, increased mechanization for tillage, seeding, spraying, and harvesting could be made available as agriculture develops.

An alternative to improved pasturage and more intensive field farming is cultivation in controlled environments. Various types of container and site-controlled agriculture, ranging from small containers to permanent greenhouses, offer potential for development of intensive agriculture in the smallest U.S.-affiliated islands. Controlled-environment cultivation may overcome some constraints posed by land and freshwater availability, high land prices, unproductive and highly erodible soils, and pest and disease outbreaks. Such technologies (hydroponics, greenhouses, and shadehouses) already have been implemented on some islands with varying degrees of success. Yields from container agricul-

ture commonly are very high although labor and water requirements also are high.

Tropical greenhouses permit growth of crops that cannot withstand heavy rainfalls typical of the tropics. Shadehouses are used throughout the islands for tree and perennial crop propagation and may also be used to grow cool-season crops sensitive to high temperatures and long day lengths. Hydroponics—a totally controlled system with artificial growth media, and high capital requirements—is probably feasible only for certain high-value herbs and vegetables. Such systems have been successful in the U.S.-affiliated Caribbean islands and on Guam, and are technically suitable for other islands where water supplies are adequate.

Very high-value specialty crops offer another possible commercial agricultural opportunity for many islands: spices, essential oils, specialty fruits and vegetables all have development potential and some (Pohnpei black pepper) have already penetrated world gourmet markets. High returns to labor and management are possible from small plantings. Strict quality control would be necessary which may initially require private joint ventures or government management.

Strategy: Develop Commercial Forestry

Commercial forestry development may be possible on some lands unsuitable for other uses. The forestry program in Puerto Rico, a cooperative operation with the U.S. Forest Service, has had considerable success in species enrichment of forests and in increasing total forest cover. The USVI Urban Forestry Program provides mahogany culled from roadside plantings to small-scale furniture and crafts producers. Forests in the Pacific islands commonly are used for construction materials, charcoal, and fuelwood, but little forest maintenance, enrichment, or reforestation is practiced. Reforestation or afforestation of severely degraded lands may renew soil productivity to allow profitable use of these lands.

Strategy: Develop Research Programs Relevant to Island Needs

In order to accelerate agriculture development, research programs need to be directed to specific goals relevant to island development. Although the need for research is widely recognized, the research capacity of many U.S. island institutions is limited. Research is hindered further by inadequate or unavailable baseline data and skilled research staff. The U.S. Department of Agriculture (USDA) has designated research institutes for tropical agriculture (the Universities of Puerto Rico and Hawaii) and for tropical forestry (the Institute of Tropical Forestry in Puerto Rico and the Institute of Pacific Islands Forestry in Hawaii). However, funding for these institutions has declined in recent years.

Research performed by local institutions could be supplemented by taking advantage of research performed by other regional institutions. Research performed by the University of the South Pacific, the South

Pacific Commission, the Caribbean Agriculture Research and Development Institute, and other regional research institutions can provide useful information. It probably would be to the advantage of small island governments to establish cooperative relationships with appropriate international research institutions or major universities that can assist in basic research.

Nearshore Fisheries and Aquaculture

Islanders have harvested tropical aquatic organisms for a tremendous range of utilitarian, symbolic, and ornamental functions since prehistoric times. The sea was important as a food source in the Caribbean and supplied an estimated 90 percent of the Pacific islanders' animal protein. Fishing was an integral part of traditional high island socioeconomy and essential to life on atolls. Today, as in the past, marine resources still supply a large percentage of consumed protein.

Tropical nearshore environments are biologically complex and variable. Ecologic structure and composition vary widely within and among islands, even over short distances. Nevertheless, nearshore ecosystems in the islands generally comprise three distinct, but intimately interrelated habitats: 1) mangrove forests, 2) seagrass meadows, and 3) coral reefs. Many animals migrate among the habitats during different times in their life cycle, and nutrients are efficiently captured, retained, and recycled. However, these systems are highly susceptible to disruption

Photo credit: C. Wahle

Nearshore fishing takes place primarily in the vicinity of coral reef ecosystems, a major feature of atolls and tropical nearshore waters.

and degradation by natural or manmade stresses. Natural recovery processes can take decades once the source of stress is removed.

Nearshore resources effectively are the social security reserve and unemployment insurance of many island people. Further damage to these resources and/or resource depletion through overcapitalization of fisheries may have an extremely high opportunity cost in terms of public assistance, food imports, and social costs of diminished self-esteem.

The major constraints to nearshore tropical fisheries development include inadequate knowledge of complex ecosystems, inherently limited productivity of offshore waters, and vulnerability of tropical fisheries to natural and human disturbances. Equipment maintenance and servicing, and problems of transporting inputs and exports also hinder development. Scientific information on the current status of nearshore marine resources is fragmented and inconclusive. Without concise data on resource distribution and abundance, the concept of optimum sustainable yield is mere technical jargon.

Most research and classical models of marine biological systems have been based on continental shelf areas of the Northern Hemisphere. The physical differences between reef slopes of oceanic islands and continental shelves, and the diversity and complexity of tropical sea fisheries reduce the value of these biological and bioeconomic models. The effects of selectively fishing certain species, fishing the same species at different depths, the relationships between nearshore and offshore stocks, and fish population dynamics, are less well understood in tropical than in temperate waters.

Strategy: Support Subsistence and Small-Scale Commercial Fisheries

Nearshore marine resources are susceptible to overexploitation, thus, technologies that simply increase nearshore harvests probably will have long-term negative impacts on fisheries' potential. The productive capabilities of nearshore systems have already been exceeded in many areas and are being approached rapidly in others. Therefore, little potential exists for significant, sustainable expansion of these fisheries.

Subsistence and small-scale fisheries are nonetheless important for their food-, income-, and employment-generating potential. As nearshore resources have come under greater pressure, fishermen have increasingly moved offshore and/or made more use of migrating pelagic species sometimes found in lagoons and at reef edges. Such resources, as well as other underexploited species (possibly shark, deepwater shrimp, and other species beyond reefs) probably offer opportunities in the U.S. Caribbean and Pacific for expansion of small-scale fisheries—commercial, recreational, or subsistence. Development policies in both areas emphasize underused marine resources. In some cases, it might be possible to develop fisheries for species not desired locally, but valuable as export commodities. However, even underexploited resources can become quickly depleted without careful management.

Strategy: Develop Aquaculture

Aquaculture, the cultivation of aquatic organisms in fresh, brackish, or marine waters, began over 2000 years ago in China. Interest in aquaculture is apparent in the U.S.-affiliated tropical islands. Aquaculture offers a potential mechanism to supply fishery products to local markets, increase job opportunities and income in rural areas, generate export dollars, and supplement marine resources through reseeding programs.

Systems range from low maintenance marine enclosures to intensively managed hatcheries and raceways, and from subsistence production to production for commercial markets. Applicability of these techniques may depend on many factors: including availability of appropriate sites; technology, capital, and labor requirements; and market potential.

Sea ranching involves collecting and growing wild or cultured stock—usually sessile or sedentary species—under managed natural conditions. This carries the benefit of a secure food source, but also the risk that natural stocks will be collected too rapidly, reducing natural productivity. Control and conservation measures may mitigate this problem,

Culture in natural waters includes bottom and near-bottom intertidal and subtidal culture of sedentary species (clams, oysters, conch, seaweed). This is practical only where natural supplies of phytoplankton

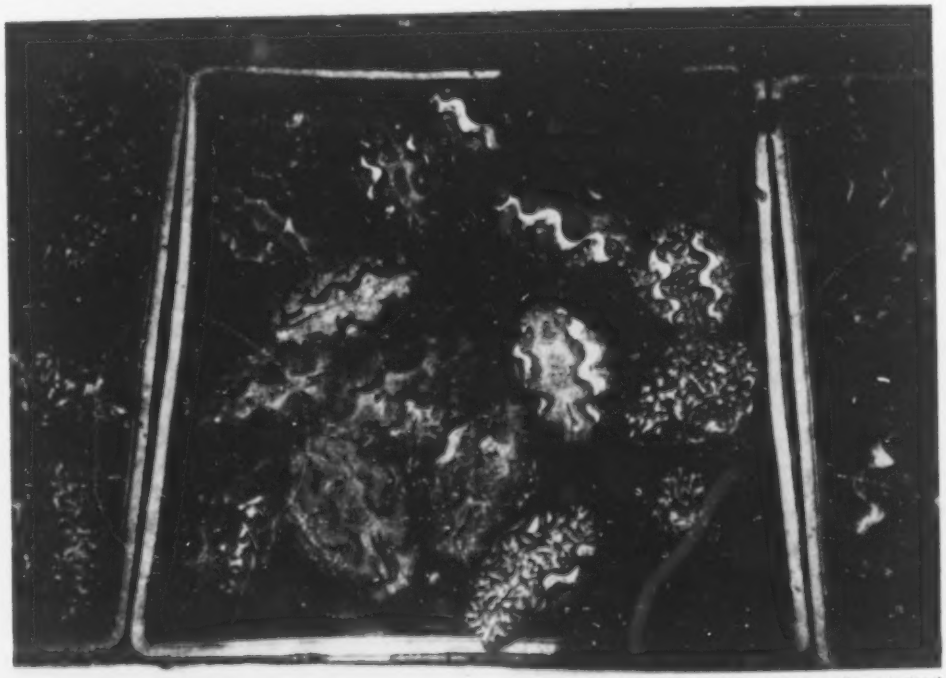

Photo credit: Office of Technology Assessment

Techniques have been developed at the Micronesian Mariculture Demonstration Center in Palau for culture of giant clams—unique among farmed animals in that they derive their nutrition from symbiotic algae embedded in their mantles and thus require no supplemental feeding.

are sufficient to serve the food needs of cultured species—generally these areas are restricted to larger islands. Seaweed cultivation, on the other hand, may be well suited to small, remote islands, since the thalli can be sun-dried and stored for many months.

Culture of marine fish in floating net pens or cages is possible where space is available in protected estuaries and bays. Several species of finfish could form the basis for mariculture in the Pacific and Caribbean.

A variety of crustaceans (prawns and shrimp) and fish (rabbitfish, milkfish, mullet, redfish, tilapia) are suitable candidates for fresh or saltwater pond culture on U.S. islands. Commercial ventures based on pond aquaculture have been developed on Guam and Puerto Rico. These have had mixed success, but interest in this form of aquaculture remains high. There is potential for expansion of pond farming in both regions not only to raise food species, but also high-value species for the aquarium trade, and bait fishes to supply tuna fisheries.

All of these forms of aquaculture are possible in tropical environments, however, adaptive research is required to test the applicability of specific culture systems to local environments and species. Technologies must be socially acceptable and economically feasible. Logistical constraints such as difficulties in supplying inputs and delivering products should be considered.

Land availability constrains the development of extensive pond aquaculture on most islands. However, semi-intensive commercial operations may have some potential. Such operations, which are already being developed in Puerto Rico, are characterized by smaller, more engineered and managed ponds, more supplemental feeding, and higher stocking densities than extensive systems. Intensive culture involving even higher degrees of environmental control and technical expertise probably is not yet feasible for most U.S. islands. Aquaculture development in many island locales may be most successful where simple methods are used to produce high-value species to supply hotel and tourist facilities.

TECHNOLOGIES TO SUPPORT RESOURCE DEVELOPMENT

Several constraints to resource development might be addressed through appropriate technologies for food storage, processing, distribution, and marketing. In general, reduction of crop losses and maintenance of product quality is easier than expanding and intensifying sustainable production. Tropical diseases, pests, and spoilage all take a toll on crops and livestock before and after harvest. Nearly 30 to 40 percent of island crops may be lost to a combination of these factors.

Preharvest Control Technologies

Appropriate pest, disease, and weed control can contribute to reduction of losses and damage, and thereby, effectively increase yields and marketability of crops and livestock. Use of pest- and disease-resistant

crops is a traditional strategy that might be more widely applied on the islands following development and field trials. Certain traditional cropping systems also serve to control pests, i.e., polyculture (with some plants serving as pest barriers), field and crop rotation, and careful timing of plantings.

Chemical controls are easily applied and immediately effective, but may destroy the natural balance between pests and their natural predators, leading to more severe problems in the future. The effectiveness of chemical controls generally is short-lived and environmental contamination poses a serious risk.

Biological control employs the use and manipulation of natural predators to control pests, and may be preferable to chemical controls. However, considerable research, experimentation, and field trials will be necessary to identify appropriate control agents. A balance of biological and chemical controls, and polyculture may offer the best long-term pest/disease control strategy. Highly skilled and motivated agricultural extension services will be integral to the success of this strategy. Strong quarantine programs to prevent reinfestation could complement such efforts.

Food Preservation and Processing

Improved storage and transportation could greatly reduce postharvest loss of agriculture and fishery products to spoilage, insects, rats, and other pests. Refrigeration can achieve these results, but generally it is constrained by lacking or irregular power supplies. Newly developed solar-powered refrigeration systems offer some promise for cold storage at remote localities; however, development costs would be high initially.

Other methods of food preservation and processing range from traditional sun-drying and smoking of fish and coconut meat to modern freeze drying and canning technologies. Some processing and preservation methods are practiced on the islands, and others which are not yet practiced might be applicable. However, most modern processing technologies are energy-intensive and therefore expensive. Establishment of regional or local cooperative food processing centers may make processing more affordable.

Market Development

Steps to develop local markets for island products could include gradual increases in the use of locally produced commodities for federally funded programs, for U.S. military personnel, and for tourists. Currently, only limited amounts of island products enter into these markets. Several factors hinder greater reliance on local products by these sectors, including irregular and limited supplies, and irregular product quality.

There is potential for development of regional markets in the Pacific, but this will depend on strengthened transportation services, and establishment and/or revision of quarantine regulations. In the Pacific, Guam

and the CNMI have better export potential because of air transport links with Japan. Currently, Japanese markets remain closed to Micronesian exports because of strict quarantine regulations.

Removal of import tariffs from Caribbean basin countries has seriously reduced the potential for export of fresh produce from Puerto Rico. To increase exports under these conditions, Puerto Rico probably will need to both reduce production costs and improve product quality to become more competitive.

Cooperatives

Cooperatives seem to be a practical way of organizing and mobilizing capital and people in developing communities. Local producers might be encouraged to expand crop production if cooperative processing and/or marketing facilities guaranteed sale of surplus produce. Agriculture and fishery cooperatives can also competitively purchase supplies, services, and equipment that individuals cannot afford. The more highly organized cooperatives provide fully integrated programs for their members, and cover equipment purchases, offer assistance in processing and marketing, and even research and development.

While some cooperatives are successfully operating on the islands (e.g., Saipan Farmer's Cooperative Association), others have struggled or failed. Local governments might encourage their development through investing in infrastructure and providing tax benefits and technical assistance.

Vertical Integration of Operations

Contract farming to vertically integrate small farmers with large agricultural production/ processing and marketing operations is likely to help increase food production on U.S.-affiliated islands. Small farmers contract with a large company to raise products, which the company purchases at a guaranteed price, processes, and markets. The company may also provide farmer-contractors with some agricultural inputs and production assistance. Such enterprises are capable of economies of scale and benefit both producers and consumers. There are several successful, vertically integrated agricultural enterprises in Puerto Rico. Black pepper production on Pohnpei is also integrated, although the processing and marketing unit is government run.

TECHNOLOGIES TO SUPPORT RESOURCE SUSTAINABILITY

Agriculture cannot be a productive sector of island economies if soils become too nutrient-depleted or if soil erosion is uncontrolled. Maximum economic yield cannot be attained offshore if marine resources are harvested indiscriminantly. Many technologies supportive of resource sustainability are aimed at minimizing depletion, and at regulating use of resources.

Soil Conservation

Soil erosion and degradation is greatest in conventional clean-tilled row-cropping, particularly when fallow periods are short. Prevention might include lengthening fallow periods to take advantage of the natural regeneration capacity of the ecosystem, restricting and controlling burning, and applying soil-conserving cultivation and culture practices (i.e., terracing, contour farming, mulching, conservation tillage, and planting of soil-conserving crops and hedgerows).

Each technology has advantages and disadvantages. For example, conservation tillage contributes to reducing soil erosion and labor and equipment requirements, and increases soil moisture retention. However, this technique relies heavily on herbicides for weed control and creates potential habitat for pests. Contour farming is inexpensive, but becomes less effective as the inherent potential for erosion increases. Steep lands can be terraced, but surface compaction and ponding may result. Terrace construction is expensive and may require removal of topsoil from large areas. Considerable expertise will be needed to determine which soil-conserving technology is appropriate for application in a specific area.

Photo credit: Office of Technology Assessment

Plastic mulches, applied here on St. Croix, USVI, serve to inhibit weed growth and enhance soil moisture retention.

Soil Amendments

The development of local soil amendments may be necessary to offset the nutrient draining effects of commercial agriculture technologies. Most soils in the islands are relatively nutrient poor due to a variety of factors, thus, the need for fertilizers (organic or commercial) to produce and sustain commercial yields is imperative.

Despite evidence that tropical soils respond much differently to such fertilizers than temperate soils, and despite the potential adverse impacts of fertilizers on groundwater and marine ecosystems, commercial fertilizers are commonly used on the islands. Research is needed on other methods of maintaining soil fertility such as green manuring, intercropping with legumes, fallow periods, and crop rotation. The possibility of using municipal wastes as compost also might be explored. Evidence suggests that the efficiency of commercial fertilizers may be increased if they are used in combination with organic fertilizers and/or mycorrhizae, or with zeolite minerals.

Fisheries

For many Pacific islands, management of resources to ensure sustained yield is even more imperative in the marine than in the terrestrial environment. These resources provide for many subsistence needs and represent a food reserve in the event of natural calamities.

Modern Regulatory Measures

Although marine resource management was traditionally practiced by islanders, rigorous scientific efforts to manage these resources are relatively recent. These commonly involve regulatory measures to restrict harvest methods and seasons in order to conserve individual stocks and to restrict access to critical habitats. The Caribbean Fishery Management Council has placed restrictions on types of gear that may be used for harvest and has established minimum permissible sizes for some species. Other restrictions on seasons or areas are also possible, but have not been enacted. Modern management efforts in the Caribbean and the Pacific are also limited in that they focus on single species or groups of species rather than on entire ecosystems.

Parks

Ultimately, some extremely sensitive ecosystems may have to be given special status as marine parks or reserves. Ecosystems such as coral reefs and mangrove forests which are important habitat for many marine species and are highly vulnerable to degradation are prime candidates. As yet there are few protected marine areas in the U.S. island territories. If successfully sited, established, and managed, marine parks and reserves could protect critical areas, and also provide a source of recruitment for restocking exploited surroundings.

Traditional Management Methods

While fishing efforts might be limited by any or all of the above methods, enforcement is difficult in tropical areas where species numbers

Photo credit: Office of Technology Assessment

The Ngerukewid Islands Wildlife Refuge in Palau, encompassing 640 acres, includes considerable open marine areas and unique marine lakes.

are high, and catch and market data are scarce. Biologists also know less about tropical than temperate fisheries. Despite attempts to protect overexploited resources, western cultures largely have been unable to manage tropical reef fisheries efficiently. Traditional management measures are a part of village lore in some Pacific islands. Some management measures, reveal a sophisticated knowledge of ecological relationships. Traditional use rights in fisheries (TURFs) of the Pacific islands are based on the principle of limited entry and other conservation strategies. TURFs continue to play a major role in some island cultures. On some islands, they have been seriously disrupted by western technologies and by economic pressures of commercialization.

Existing TURFs may contribute to fisheries conservation in the U.S. Pacific islands. Management schemes and regulations recognizing traditional marine tenure in the islands could be established. Private enterprises, such as seaweed and giant clam farming, pearl culture and trochus fisheries, would be likely to respond well to exclusive ownership. In areas where TURFs have lapsed, local management and enforcement responsibilities could be instituted.

TURFs cannot, however, guarantee successful conservation. TURF systems are diverse and some are more useful in fishery management than others. TURFs pose an impediment to commercial tuna fishermen who obtain bait fish from these areas, often with great difficulty. TURFs may also impede nearshore harvest of migratory pelagic species.

Artificial Habitats

Management of marine resources for sustained yields might also involve use of artificial reefs and fish aggregation devices (FADs). Artificial reefs range from scrap automobiles and tires to specially designed and engineered structures. Whether the introduction of artificial reef habitats enhances overall fisheries productivity or merely increases local populations by attracting fish from elsewhere is not known—there is evidence for both results. FADs are anchored buoys placed beyond reefs to attract pelagic fish. Although catch rates are significantly increased by their deployment, the impact of FADs on regional fish stocks and the sustainability of high catch rates have not been evaluated. Until such questions are answered, artificial reefs and FADs probably cannot be determined to contribute to fisheries management for sustained yields.

TECHNOLOGIES TO SUPPORT RESOURCE RECOVERY

Extensive degradation of terrestrial resources and overexploitation of nearshore marine resources is apparent in many insular areas. Programs aimed at resource restoration and recovery will likely be important to long-term ecologic and economic stability of the U.S.-affiliated islands. A primary cause of soil and land degradation has been forest clearing, thus, revegetation programs represent a potential strategy for improving terrestrial productivity. Traditional and commercial agroforestry, short or long rotation forestry, or growth of ground cover in the form of nitrogen-fixing legumes all offer possible options. Selection of plant species and of rotational strategies is critically important to the creation of stable and productive ecosystems. Reforestation or afforestation of degraded lands brings many benefits aside from products. Forests contribute to reducing wind erosion, protect and improve soil fertility, regulate soil water and contribute to flood control. They also provide wildlife habitat. Agroforests provide the additional benefits of mixed cropping.

Like terrestrial forests, mangrove and seagrass habitats have suffered extensive damage. Success of natural or induced recovery schemes is variable, but recovery programs represent management options. Few attempts are currently being made to restore such habitats. From an ecological viewpoint, the best strategy is probably to protect these habitats from adverse impacts. They are valuable resources that may take up to 100 years to recover naturally, if at all. Where possible, restoration is costly and success is not guaranteed.

As the nearshore resources of the Pacific and Caribbean regions are becoming overfished or degraded, the idea of enhancement and reseeding of these resources is gaining attention. Restoration of marine resources generally means restocking of selected species. Farming, or aquaculture of marine organisms may become important to restock or reseed depleted fishery stocks. However, without appropriate controls on subsequent harvests, a reestablished population may be exploited at a greater than optimal rate and possibly reextinguished.

Integrating Technologies

Many technologies for renewable resource development can be integrated with technologies for energy production and conservation, waste treatment, or with each other. Potential exists for development of energy integrated farms, and operations that integrate aquaculture with agriculture, waste treatment, and energy production.

Energy Integrated Farms

Energy integrated farming offers a means of transforming animal and crop wastes into useful products. Organic matter is fermented into biogas (a methane-rich gas mixture) and a thick slurry in oxygen-free digestors. Completely fermented slurry is virtually odorless, has reduced harmful organisms, and retains the fertilizer value of the original materials. It can be used as a livestock feed additive, potting soil, and fertilizer. Biogas can be used to generate light, and to operate stoves, refrigerators and even modified gas engines.

The quantity of useful products depends on the amount and type of organic matter, digestor capacity, and ambient temperature. A broad scope of applications are possible, ranging from small, single-household digestors, to huge "high-tech" complexes requiring corporate backing. Widespread application is constrained by lack of large livestock operations, design and operation expertise, and capital.

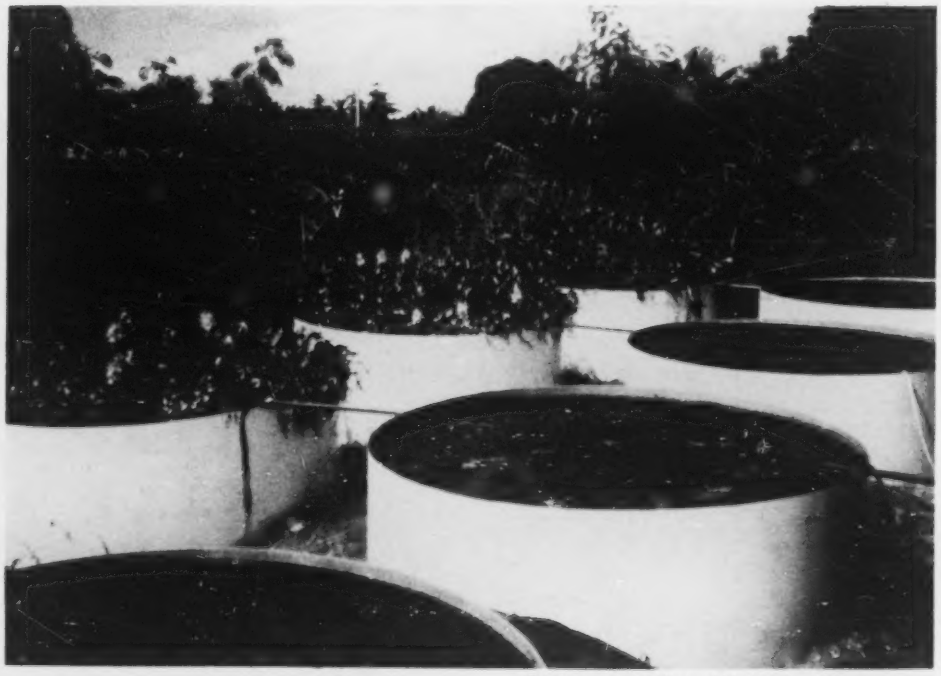

Photo credit: Office of Technology Assessment

Slurry from biogas digesters can be directed through aquaculture—here, tilapia and water hyacinth culture—before being discharged through agricultural irrigation systems, providing numerous additional benefits to energy generation.

Use of energy-integrated farming technologies in the near term will probably be limited to a few farmers with large manure supplies and sufficient water resources for system operation. Within 8 to 10 years, small-farm biogas units could probably be implemented more widely. Energy derived from animal and crop wastes, wood, and other plant materials offer a potentially important substitute to imported oil for many islands.

Aquaculture/Energy Production Systems

Considerable energy is needed to pump seawater to mariculture farms. If such farms could be integrated with powerplants, which pump and discharge large quantities of water for cooling, considerable savings might be realized. Powerplants and mariculture systems could be designed to maximize benefits. Water pumped from under the thermocline is relatively rich in nutrients for aquaculture and would provide cooling for the powerplant.

Integration of aquaculture with innovative forms of energy production that exploit the energy of the sea (i.e., ocean thermal energy conversion systems, wave energy systems and hypersaline solar ponds) may also be possible once such systems become available in the form of low-cost simple technologies. Integration of aquaculture with these technologies may enhance their economic feasibility for some islands.

Waste Treatment Systems

Cultivation of seaweeds or other aquatic plants has been integrated with water treatment in the United States and has potential for application on tropical islands. There may also be opportunities for increasing agricultural productivity with land application of sewage sludge, treated wastewater, and municipally derived compost.

Planning/Policy Considerations

Improved resource management planning requires careful consideration of development constraints and opportunities as well as numerous other factors: information needs, possible sources and management, choice of strategies for plan implementation, and the role of traditional law and local people in management planning and implementation.

Each of the U.S.-affiliated island governments has designated a Planning Office to compile information on factors affecting economic development and to present a framework for rational development planning. A number of plans analyzing resource management and development activities have been prepared in each island area either by these offices (e.g., Coastal Zone Management plans) or by the United Nations. However, different plans are rarely centralized or aggregated. The 5-year comprehensive development plans prepared by the Freely Associated States (under the terms of the Compact of Free Association) tend to be too general to provide real guidance to decisionmakers. Planning processes may go awry for these and other reasons, including:

- inadequate "in-house" planning expertise and heavy demand on existing island planners,

- inadequate problem specification,
- lack of understanding of natural processes,
- inadequate specification of management alternatives,
- use of planning as a substitute for management,
- lack of resources for planning, and
- lack of understanding of the social and political contexts in which plans are to be implemented.

Information Procurement and Management

A primary obstacle to the development of baseline ecological surveys is the cost of data collection, storage, and retrieval. Since few islands can afford a major data acquisition effort, an initial priority could be to ensure collection of data essential to program implementation. An incremental approach could then be taken to collect desirable data, this could emphasize the use of island residents as sources of resource-related information.

Within many governments, data are collected by more than one agency, sometimes resulting in duplication of effort. Data may be collected in different formats and on different scales making sharing of information difficult. Opportunities to ameliorate these problems include re-organization or centralization of data collection, storage, and processing responsibilities, and ensuring coordination among various agencies that currently share these responsibilities. An island-by-island assessment of data collection could be a first step toward identifying opportunities for data sharing, and for collaboration on new data acquisition.

Traveling workshops could provide short-course training on information collection and mapping techniques. Distribution of data to users may be facilitated with data lists and inventories; reproduction of reports, air photos, and maps; workshops and seminars; and participatory approaches to planning.

Analytical Planning Techniques

Restriction of resource use to activities with minimal adverse impacts is currently the dominant approach to resource management on the U.S.-affiliated islands. In the short run, therefore, environmental impact statements (EISs) will probably remain the primary technique used for resource and plan assessments. Several "off-the-shelf" approaches to impact assessment make it a relatively cost-effective and simple procedure. A review of procedures for conducting EISs could help planners develop those most relevant to island environments. Post-project evaluations are one way to reveal the strengths and weaknesses of current EIS procedures.

Environmental impact analysis, however, is a short-term investigation of the likely impacts of previously identified policy or project options and, thus, does not permit evaluation of the full range of development alternatives. Other methods are being developed to allow consideration of environmental and resource information early in resource development planning, including resource suitability analysis,

carrying capacity analysis, extended benefit/cost analysis and multi-objective analysis. Few of these techniques have been applied to U.S.-affiliated islands. If such methods were fully developed and implemented, however, repeated EISs might be rendered redundant.

Resource suitability analyses, which can range from simple map overlays to complicated computerized geographic information systems, provide information about the supply of resources at various levels of suitability for various uses. Such analyses generally comprise a method of delineating landscape or seascape units on a map and assessing the capability of these areas to sustain an array of potential uses without unacceptable degradation and given certain levels of management and technology. Carrying capacity analysis, a method of determining the optimal human population that can be supported at given levels of technology and amenity, also has been used to help identify critical resource use decisions.

Benefit-cost and multi-objective analyses both attempt to encompass the array of secondary and intangible benefits and costs from alternative programs or projects. Benefit-cost analysis incorporates value judgments regarding the translation of unquantifiable variables and social preferences into money values. Multi-objective planning does not force all effects into the same measurement units, but relies on decision-makers' assignment of relative or weighted values for each category of impact.

Although based in science, interpretations of factors such as custom, skills, innovativeness, likely technology and institutional capability come into play in making the ratings. Thus, each technique depends on expert judgment and public participation as well as on manipulation and interpretation of scientific information.

Participatory Approaches to Planning and Management

The need to incorporate public participation in resource development planning is based on several factors: 1) local knowledge and understanding of an area's natural systems often complements or exceeds scientific knowledge, 2) public participation in resource-related planning and policymaking may yield benefits in compliance and enforcement of local regulations; and 3) actions that respect people's priorities and that are planned with local input and approval are more likely to succeed than actions that require intensive regulation and enforcement.

Generating public participation in resource management projects can be extremely time-consuming and costly. In order to tap local sources of information, it usually is necessary to give equally in return. The following conditions have been suggested as guidelines for public participation in resource management:

1. **long-term presence** to understand a community's structure, build rapport, and foster mutual respect;
2. **local involvement in all aspects of a project** from design to implementation, as well as respect for local input and objectives;

3. **local participation in concrete activities** from which people can gain tangible benefits; and
4. **education and research activities in which local people are equal partners** with government, project staff, and professionals.

Modern Law and Traditional Custom

Custom is a valued asset of U.S.-affiliated island communities. Values such as respect for traditional leaders, consensus-based dispute resolution, and significance of clan membership have survived the impact of colonization and modernization, and form a significant part of the identity of island peoples. The opportunity exists to blend traditional management methods and the democratic system as Micronesia develops self-government. One advantage of retaining traditional methods of guiding social behavior is that these require no legislative decree or policing—they are ingrained in local belief and custom. Traditional resource management tenets often have ecologic rationale.

A formalized system for incorporation of Pacific island custom into a system of law appropriate for use in island societies could include: explicit recognition in constitutions, statutes and case law of the value and primacy of custom; recognition of custom whenever a new law is adopted; and court adherence to the constitutional and legislative mandates to preserve custom. Judges knowledgeable of local customs could use that knowledge in decision and rule-making in a way that ensures preservation of customary values and principles. Further, they could recognize that access to resources is a part of the livelihood of island peoples, and that complex systems of ownership and use have evolved that do not resemble western concepts of ownership. In resolving resource-related disputes, judges may wish to delay intervention until traditional leaders are consulted and other methods of dispute resolution are exhausted.

SUMMARY OF ISSUES AND OPTIONS FOR THE U.S. CONGRESS

Economic growth of the U.S.-affiliated islands is likely to be largely dependent on the sustainable development and management of renewable resources, and on a tourist industry that is compatible with development and management goals. As the primary policy-making body for the islands, Congress can foster pursuit and achievement of these objectives in a variety of ways:

- by tuning appropriate Federal agencies and assistance programs to the special situation and needs of islands;
- by coordinating the work of agencies responsible for various aspects of resource management on the islands;
- by making opportunities for Federal assistance directed at developing sustainability of resource uses readily apparent and more easily available to islands; and

- by providing additional assistance in the areas of data collection and management, planning, education, extension, training, and research.

Various options exist within all of these areas to improve and expand Federal support for agriculture, forestry, fisheries, and aquaculture development on the islands.

Congressional Oversight and Federal Agency Coordination Issues

This study reveals important links among renewable resource use, environmental protection, island cultures, political systems, and economic development. However, no single congressional subcommittee of the House Committee of Interior and Insular Affairs, or of the Senate Committee on Energy and Natural resources is structured to deal with all of these interrelated issues as they apply to resource management on the islands. Activities related to the U.S. islands, moreover, are spread through many programs of USDA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of the Interior (USDOI), making coordination and congressional oversight difficult. The USDOI's Office of Territorial and International Affairs (OTIA) is responsible for promoting the economic, social, and political development of the U.S.-affiliated islands and for analyzing, developing, and coordinating USDOI's policies and programs pertaining to international activities.

To take advantage of the OTA findings in this assessment, mechanisms are needed to coordinate and perhaps increase appropriate support of Federal island-related activities and to facilitate congressional oversight of these activities.

Option: New Congressional Subcommittees.—Congress could establish new House and Senate subcommittees to deal with integrated resource management on the U.S.-affiliated islands.[1] These would provide focal points within Congress where approaches to island resource development could be handled and integrated. This could benefit island officials and strengthen existing links between the U.S. Government and the U.S.-affiliated islands. The importance of the islands to national security will probably increase in the next decade, making such links more important. Alternatively, Congress could establish a congressional Joint Territorial Policy Study group to analyze island matters requiring congressional action.

Option: Increase Federal Program Coordination.—Congress could hold oversight hearings on OTIA coordination of Federal agencies programs and plans for activities in the islands. Alternatively, or in addition, Congress could authorize and support establishment of an Interagency Coordinating Group on Resource and Economic Development in U.S.-affiliated islands which could represent the relevant Federal territorial policy and resource-related Federal agencies. This group could assess current insular participation in Federal resource programs, identify means for integrating programs within and among agencies into

more effective and cost-effective packages and suggest funding priorities for technical assistance from the agencies. Representatives could serve as insular government contacts with Federal agencies.

Finally, Congress could designate the U.S. Man and the Biosphere Program (U.S. MAB) as the lead coordinating agency for Federal resource-related activities on the islands and encourage increased coordination between U.S. MAB, OTIA and other Federal agencies, in addition to those already involved in U.S. MAB activities. Research on the ecology and rational use of small island ecosystems has been identified as a priority for U.S. MAB support. Increased support for the U.S. MAB islands program could allow expansion of research and training in the U.S.-affiliated islands, especially in the Pacific, where the MAB Directorate has been inactive, and could improve coordination of federally supported, resource-related activities in the islands.

Option: Review Effectiveness of Federal Island Programs.—Many executive agency programs focused on island resource issues receive favorable comment from island resource managers, planners, and government representatives, some do not. To help determine which approaches have worked best in the islands and which ones should be modified to improve their chances of success, Congress could direct USDA, NOAA, and USDOI each to evaluate the effectiveness of their own programs related to renewable resource management on the islands, and to appear at oversight hearings related to island issues.

Alternatively Congress could direct the General Accounting Office to conduct such reviews. While individual agencies are familiar with their own programs' details and likely could perform reviews more easily, there may be advantages to having an outside agency perform the task.

Data Collection and Information Management Issues

A first requirement for resource and economic development planning in the U.S.-affiliated islands is to collect comprehensive and up-to-date resource, economic, and social data and make it easily accessible to planners. Techniques also are needed to store, synthesize, analyze, and manipulate data in ways useful for resource development planning. With the modern, reasonably inexpensive computer systems available today, data storage, synthesis, analysis, and dissemination are not insurmountable problems.

Existing natural resource databases on most islands generally are inadequate, as are the appropriate economic and social data needed for informed judgments on future island development. Efforts to collect data in several broad areas could greatly assist planners. For example, in order to minimize the possibility that economically or environmentally inappropriate agricultural technologies are introduced on islands, and to determine which production technologies have the greatest chance for ready and profitable adaptation, there is a need for specific information on existing farm operation methods. Before new aquaculture or fisheries technologies are introduced, similar marine resource

use data must be collected. While local departments of marine resources collect aquatic and fisheries data in the Caribbean, there is no data collection and aggregation structure for the Pacific Islands.

The U.S.-affiliated islands also have difficulty in identifying what island-relevant Federal data/information programs exist, and which of various Federal agencies house what kinds of data that might be useful for resource planning.

Option: Analyze Island Databases and Information Management Systems.—Congress could direct USDOI to lead an interagency task force with island representation to conduct a critical evaluation of the natural resource, social, and economic databases, and data-handling methodologies for the various U.S.-affiliated islands. The task force could report to Congress on the status of island databases and on data management needs of the islands, including both equipment and personnel needs. At subsequent hearings, Congress could determine appropriate actions. Such an analysis has long been needed and could foster improved linkages between the Federal agencies and island governments. However, it may be argued that immediate direct action to collect needed data is preferable to "another study."

Option: Assess Federal Data and Information Programs Likely To Be of Benefit to the U.S.-Affiliated Islands.—Congress could direct USDOI to lead another, perhaps subsequent, interagency task force with island representation to assess the data/information and programs of each Federal agency likely to benefit islands in integrated renewable resource management and planning. A summary of findings could be published, and congressional hearings held. This action could reduce the possibility of duplicating data collection efforts or of overlooking Federal programs that could be applied appropriately to the islands, as well as expedite island resource-related planning activities.

Option: Establish Regional Information Clearinghouse(s).—Congress could establish, or support one or more existing regional island centers (e.g., the Pacific Basin Development Council, East-West Center, Micronesian Area Research Center Information System, Eastern Caribbean Center) to act as a clearinghouse for: Federal announcements on new programs pertaining to islands; island government announcements; similar international program information; market information on agriculture and aquaculture; and information on specialty, background, and availability of various island experts. Once gathered, this information could be assessed and disseminated to island governments.

Such a structure could facilitate and speed communications between the continental United States and the affiliated islands, and possibly between the Pacific and Caribbean regions. However, development of this network would require additional funding at a time when new funding is scarce.

Option: Reactivate USDA Minor Economic Crops Computer Database.—USDA previously maintained a database on minor economic crops, many of which could grow in tropical climates. This database

no longer is kept active, and no other similar database is known to exist. Congress could direct USDA to reactivate, update, and maintain this database, and continue to include information on: climate and soil conditions necessary for various crops, crop yields, nutritional and medicinal properties of various crops, and their potential for intercropping and for use in agroforestry.

The database provides one mechanism for information sharing between the Caribbean and Pacific islands, and historically costs little to maintain.

Option: Develop Small-Scale Island Farmer and Fishermen Profiles.—Congress could direct the USDA Extension Service to gather data and prepare profiles of small-scale farmers in the U.S.-affiliated islands for use in the process of identifying environmentally appropriate and economically beneficial agricultural technologies for introduction to the islands. While such profiles are being developed the rate of new technological implementation might be slowed, but the risk of unsuccessful introductions also may be reduced. In addition, Congress could direct the Sea Grant Marine Extension Service to develop Artisanal Fisheries Profiles, similar to the farmer profiles.

Option: Fisheries Statistics Collection.—Congress could provide funding to the Pacific Fisheries Development Foundation for island fisheries statistics collection programs, under either the Saltonstall-Kennedy grant program or appropriations to the Central Western and South Pacific Fisheries Development Act. Sea resource atlases could be prepared using these and other data, perhaps by the U.S. Army Corps of Engineers, which has prepared atlases for some Pacific islands.

Congress could also direct the USDA National Agricultural Library to provide assistance to the Micronesian Area Tropical Agriculture Data Center at the University of Guam to include appropriate aquaculture information. An aquaculture database also could be developed at the University of Puerto Rico, or another appropriate Caribbean institution.

Option: Training in Data Collection, Management, and Use.—Congress could direct USDOI in cooperation with USDA to arrange periodic training programs on computerized data management techniques and analysis at the land-grant institutions on U.S.-affiliated islands and on Hawaii for data managers/users from island governments. Such programs could integrate current island databases, expanding their usefulness.

Where no local data collection expertise is available, U.S. agencies could allocate funds for a local person to work side by side with Federal data collectors. This on-the-job training could emphasize the need for sensitivity to eventual interpretation of data.

Research Issues

Island governments have limited capability to conduct research on other than critical local needs, and this constrains progress in several

areas of sustainable resource development. While insular research centers in tropical agriculture and island forestry exist, there are no corresponding centers for tropical aquaculture research. Funding for Sea Grant research, moreover, has been declining and program representatives in Puerto Rico and Guam have little capability to direct research towards the needs of other islands.

Federal research organizations have considerable expertise in resource-related fields and technologies. However, little research is oriented to tropical environments, and still less is aimed at the social and cultural aspects of the U.S.-affiliated islands. The findings of resource-related research conducted in the temperate continental United States do not commonly apply to tropical island areas. Reliance on such research in the implementation of Federal programs on the islands results in "environmental misfits." This has caused some of these programs to fail and may even cause hardships to island inhabitants.

Federal agency research designed for a tropical environment relates mostly to integrated renewable resource management in tropical developing countries (i.e., U.S. Agency for International Development (AID) research). The islands benefit little from this relevant renewable resource research.

Option: Increase Regional Research and Information Dissemination Activities.—The East-West Center was formed in 1972 to provide analysis of social, political, and other issues for Asia and the Pacific. Congress could direct the East-West Center to increase resource research and analysis for the U.S. Pacific islands and increase funding for such activities. Similarly, Congress could accelerate the development of the Eastern Caribbean Center to provide similar services for the U.S. Caribbean islands.

Option: Screen U.S.-Funded Research for Applicability to Tropical Islands.—Congress could direct USDA's Office of International Cooperation and Development, its Forestry Support Service, and its Soil Management Support Service to screen U.S.-funded research for findings in agriculture, aquaculture, forestry, and other renewable resource areas that can be applied to the U.S. tropical islands, and to provide this information to the islands. AID, for example, has accumulated a storehouse of information on tropical resource management planning and development in the tropics, large parts of which might benefit island governments.

A small screening committee within USDA could use the department's Current Research Information System to identify planned or ongoing research of potential benefit to the islands, and could suggest to appropriate researchers possible means of addressing issues of relevance to the islands in their projects. Small modifications in some USDA-funded research plans may result in significant contributions to tropical island agriculture if researchers keep island problems in mind.

Option: Link Tropical and Nontropical Land-Grant Institutions.—Congress could direct AID to develop a mechanism whereby Title XII-funded research activities of tropical land-grant institutions on the U.S.-

affiliated islands. This would allow for suitability testing of certain temperate technologies in tropical environments, and would likely strengthen the island land-grant institutions' activities in integrated renewable resource planning and management, as well as the United States' overall competence in tropical natural resource management. Travel costs for research exchange between island and U.S. continental researchers would be high however, reducing the Title XII funds available for research.

Congress also could direct the U.S. Department of State to assist insular government research organizations in establishing cooperative relationships with regional and international research institutions or major universities which can help with broad strategic and basic research.

Option: Extend Section 406 Programs and Funding to All Tropical Land-Grant Institutions.—Congress could extend Section 406 of the 1966 Food for Peace Act to cover all tropical land-grant institutions, and provide funding to pursue the section's two major goals, which are: 1) to provide USDA and land-grant scientists with tropical experience and training, and 2) to provide foreign nationals with a place to learn techniques and methodologies from U.S. specialists under tropical conditions. Extending funding beyond the two original tropical institutions to receive Section 406 research funds (the Universities of Hawaii and Puerto Rico) to the five additional tropical land-grant institutions that now exist (in Guam, American Samoa, FSM, CNMI, and the Virgin Islands) could substantially increase tropical agricultural research in the United States and its territories, and give island residents local access to training they commonly must seek hundreds or thousands of miles away. However, it may take years for these schools to become as productive in research as the Universities of Hawaii and Puerto Rico, during which time substantial funds must be committed.

Option: Expand Tropical Agricultural, Forestry, and Aquaculture Research.—Congress could direct USDA to increase support for applied Research in agriculture and forestry development conducted by the Tropical Agriculture Research Stations and the Institute of Tropical Forestry in Puerto Rico and Hawaii. Congress could also increase support for basic and applied NOAA Sea Grant research in various aspects of aquaculture and fisheries

Congress also could direct NOAA to establish one or more Institutes of Tropical Aquaculture Research in the U.S.-affiliated islands to serve as a center for tropical aquaculture technology development. The center could be associated with established Sea Grant institutions, but still be mandated to serve other islands.

Education, Extension, and Training Issues

Sustainable resource development programs, and maintenance of aesthetic, productive environments depend heavily on an educated, ecologically aware public, technologically capable and informed practitioners, and skilled managers. While education is well-developed in the

U.S.-affiliated islands, few primary and secondary school curricula specifically address island ecology, agriculture, or fisheries, or the relationships between environment and development, and between resources and traditional cultures. Moreover, most Pacific island colleges are 2-year community colleges necessitating off-island undergraduate and graduate level study.

Even where research information is available, and technologies appropriate to island conditions have been identified, implementation can fail if the pertinent information is not extended to potential practitioners. In part because graduate education is weak or absent, technologically trained personnel and people capable of providing training or technical advice are scarce on most islands.

Island extension offices tend to be small, underfunded, and overworked, all of which hinder their effectiveness in technology transfer. In addition, neither local land-grant colleges nor local governments in the Pacific have adequate funds to maintain the staff needed to reach remote and outlying populations. Similarly, the Marine Advisory Services of the Sea Grant programs at the Universities of Hawaii and Puerto Rico lack the staff and funds to provide assistance to other U.S.-affiliated islands, although both are interested in doing so.

Option: Develop Environmental Education Programs.—Congress could direct the U.S. Department of Education's Office of Education Research and Improvement, in cooperation with various island government units and programs involved in environmental education, to assess ecology curricula materials for potential use in island schools. Where appropriate, financial assistance could be provided to disseminate identified materials and to develop primary and secondary school ecology curricula.

Development of an "environmental ethic" in this way could reduce the need for regulatory and incentive programs to maintain environmental quality; however, some regulatory measures and incentives are still needed to prevent resource and environmental degradation in the short term. Early education in ecology could also spark student interest in resource-related careers.

Option: Increase Island Training and Extension Services.—Congress could direct USDA, NOAA, and USDOI to develop joint training workshops for field extension agents in the islands, and to apprise extension agents of the assistance opportunities offered by both local and Federal agencies.

Congress also could direct USDA to increase support of insular agricultural extension programs to allow expansion to remote populations. Congress also could direct NOAA to increase Sea Grant assistance in training and extension for aquaculture, fisheries, and marine resource management for islands having Sea Grant representatives, and to make such services available to the other U.S.-affiliated islands. This will require identification and funding of new personnel.

Congress also could direct the U.S. Fish and Wildlife Service and NOAA Office of Sea Grant jointly to supply a resident scientist to the

regions to provide expert advice on aquaculture species introductions, and to conduct the necessary backup research.

Incentive Issues

Incentives, or removal of disincentives may be necessary to encourage island peoples to undertake new or potentially high economic risk activities. These could initially include availability and knowledge of potentially profitable technologies (provided by research and extension) and ability to implement them (provided by education and training). Incentives can be technical (marketing assistance), or financial (cost-sharing). Agricultural producers, for example, must have accurate, thorough market information, and may need help in accessing markets for their products. Cost-sharing programs have, in some cases, formed the basis for local government activities to develop resource enterprises.

Some analysts argue that eligibility for and participation in U.S. income support programs creates a disincentive to investing money and labor in resource-related enterprises in the U.S.-affiliated islands.

Option: Marketing Assistance.—Congress could direct USDA's Agricultural Marketing Service to assist insular governments through three major programs:

1. the Federal-State Marketing Improvement Program, which provides funds to States to solve marketing problems through Federal-State cooperation;
2. Market News, which provides timely information on prices, demand, movement, volume, and quality of all major agricultural commodities; and
3. Agricultural Product Grading, which provides producers and marketers with meaningful grades indicative of agricultural product quality.

Congress could also direct the Department of Commerce to have NOAA's Office of Sea Grant programs assess aquacultural marketing and economics issues for island aquaculture development.

Option: Establish Insular Resource Management Cost-Sharing Programs.—Congress could establish and authorize a new USDA program to provide cost-sharing and technical assistance to individuals undertaking federally approved agriculture, soil conservation, forestry, fishery, and aquaculture activities. Local administration of such a program would mitigate travel and other problems.

Option: Analyze Income and Other Support Programs.—Congress could direct USDA and the Department of Health and Human Services (DHHS) jointly to analyze eligibility formulae for social aid, and nutritional and other impacts of such aid. If there are large numbers of people who participate, but do not substantially benefit from aid programs, support funding could be gradually reduced, or partially redirected to cost-sharing programs.

Congress could direct USDA to assess and report on the current and potential role of local produce in island school hot lunch and other food

and nutrition programs, addressing questions of nutrition, and possible economic impacts, and suggesting a target level for home-grown contributions. Increased use of locally grown foods in such programs could provide markets and incentives for expanded island agricultural activities and thus, increased economic benefits to the islands. However, local storage and refrigeration facilities may not be adequate to assure regular delivery. Food accessibility at open markets may also decline.

[1]Moving in this direction, the House Committee on Interior and Insular Affairs established a new Subcommittee on Insular and International Affairs early in the 100th Congress.

NOTE: Copies of the report "Integrated Renewable Resource Management for U.S. Insular Areas" can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, GPO stock No. 052-003-01055-1.

REGIONAL WORKSHOP PARTICIPANTS

Freely Associated States Regional Workshop

Arthur Ansin
Acting Chief of Agriculture
Moen, Truk, FSM

Herson Anson
Chief
Forestry Division
Kolonia, Pohnpei, FSM

Andrew Bilimon
Assistant Chief Planner
Office of Planning and Statistics
Republic of the Marshall Islands
Majuro, Marshall Islands

Catalino Cantero
President
Community College of Micronesia
Kolonia, Pohnpei, FSM

Michael E. Capelle
Secretary, Public Works
Republic of the Marshall Islands
Majuro, Marshall Islands

Margie Falanruw
Yap Institute of Natural Resources
Colonia, Yap, FSM

Herman Francisco
Chief
Agriculture Division
Department of Natural Resources
Republic of Belau
Koror, Palau

Michael Gawel
Chief of Marine Resources
Department of Resources and Development
Kolonia, Pohnpei, FSM

Sailas Henry
Department of Agriculture
Kolonia, Pohnpei, FSM

Noah Idechong
Deputy Chief
Department of Marine Resources
Republic of Belau
Koror, Palau

John Iou
Chief
Division of Marine Resources
Colonia, Yap, FSM

Redley Killion
State Director
Department of Resources and Development
Moen, Truk, FSM

Jewon D. Lemari
Chief, Lands & Surveys
Department of Resources and Development
Republic of the Marshall Islands
Majuro, Marshall Islands

Adelino Lorens
Acting Chief
Agriculture
Kolonia, Pohnpei, FSM

Tashiro Ludwig
Acting Chief
Marine Resources
Kolonia, Pohnpei, FSM

Roger Mori
Acting State Planner
Moen, Turk, FSM

Aren Palik
Chief
Office of Planning and Statistics
Kosrae, FSM

William Raynor
Chairman
Department of Agriculture
Ponape Agriculture and Trade School
Kolonia, Pohnpei, FSM

Michael Rody
Acting Director
Office of Planning and Budget
Colonia, Yap, FSM

Singeru Singeo
Executive Director
College of Micronesia
Kolonia, Pohnpei, FSM

John Sohl
Acting National Planner
Department of Planning and Statistics
Kolonia, Pohnpei, FSM

Abel H. Suzuky
Director
Bureau of Commerce
Republic of Belau
Koror, Palau

Mike White
Chief
Division of Marine Resources
Department of Economics and Development
Kosrae, FSM

Koichi Wong
Minister
Department of Natural Resources
Republic of Belau
Koror, Palau

Pacific Flag Territories Regional Workshop

John Banks
Vocational Rehabilitation Center
Pago Pago, American Samoa

Tofu Fia
Director
Department of Agriculture
Pago Pago, American Samoa

Bill Fitzgerald
Senior Economist
Economic Development and Planning Division
Agana, Guam

Charles B. Frear
Assistant Director, Horticulture
Northern Marianas College
Commonwealth of the Northern Mariana Islands

Pio Gaisoa
Program Manager
Office of Marine Resources
Pago Pago, American Samoa

Frank Q. Guerrero
Acting Chief Planner
Marianas Public Lands Commission
Commonwealth of the Northern Mariana Islands

Nicolas M. Guerrero
Director
Department of Natural Resources
Commonwealth of the Northern Mariana Islands

Michael L. Ham
Administrator
Coastal Zone Management
Bureau of Planning
Agana, Guam

Chris Howard
Executive Assistant to the President
Guam Community College
Agana, Guam

James A. Marsh, Jr.
Dean
Graduate School of Research
University Guam
Mangilao, Guam

Peter Nelson
President
Guam Community College
Agana, Guam

Arnold I. Palacios
Chief
Division of Fish and Wildlife
Department of Natural Resources
Commonwealth of the Northern Mariana Islands

Pemerika Tauiliili
Director for Land Grant Programs
American Samoa Community College
Pago Pago, American Samoa

Caribbean Regional Workshop

Juan A. Bonnet, Jr.
Director
Center for Energy and Environment Research
University of Puerto Rico
San Juan, Puerto Rico

Evelyn Cepeda
Director of Aquaculture
Corporation for Development of Marine Resources
San Juan, Puerto Rico

Iris Corujo
Principal Investigator
Marine/Sport Fisheries Reserves
Department of Natural Resources
San Juan, Puerto Rico

William Gladfelter
Associate Professor
West Indies Lab
St. Croix, U.S. Virgin Islands

Kenneth Green
Assistant Director
Agriculture Experiment Station
College of the Virgin Islands
St. Croix, U.S. Virgin Islands

Cecil Jennings
Department of Conservation and Cultural Affairs
St. Thomas, Virgin Islands

Joseph Kimmel
Director
Corporation for Development of Marine Resources
Mayaguez, Puerto Rico

Wallace Koehler
Center for Energy and Environment Research
Technology and Policy Assessment Division
University of Puerto Rico
San Juan, Puerto Rico

John Kubaryk
Assistant Director
Department of Marine Sciences
University of Puerto Rico
Mayaguez, Puerto Rico

Claudette Lewis
Assistant Director
Virgin Islands Office of Planning
St. Thomas, U.S. Virgin Islands

Edwin Monsanto
Environmental Specialist
Department of Conservation and Cultural Affairs
St. Thomas, U.S. Virgin Islands

Walter Padilla
Corporation for Development of Marine Resources
San Juan, Puerto Rico

Luis R. Quinones
Junta Planificacion Puerto Rico
Zonificacion Rural
San Juan, Puerto Rico

Felipe Rodriguez
Assistant Secretary of Agriculture
Department of Agriculture
Santurce, Puerto Rico

Brian Turnbull
Acting Director
Virgin Islands Office of Planning
St. Thomas, U.S. Virgin Islands

Robert Waide
Center for Energy and Environment Research
Terrestrial Ecology Division
University of Puerto Rico
San Juan, Puerto Rico

Patrick Williams
Commissioner of Agriculture
Kingshill, St. Croix

Rafael Montalvo Zapata
Assistant Director for Research
Agriculture Experiment Station
Rio Piedras, Puerto Rico

Assessments in Progress as of February 1987

Technology and the American Economic Transition
High-Technology Ceramics and Polymer Composites
Magnetic Fusion Research and Development
Competitiveness of Domestic Copper
Technological Risks and Opportunities for Future U.S. Energy Supply and Demand
International Competition in the Service Industries
Technology Transfer to China
Alternatives for Improving NATO's Defense Response
Seismic Verification of Nuclear Test Ban Treaties
Strategic Defense Initiative: Survivability and Software
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Low-Resource Agriculture in Africa
Technology and Public Policy To Enhance Grain Quality in International Trade
Monitoring of Mandated Vietnam Veteran Studies
Technology and Child Health
Nontraditional Methods of Cancer Treatment: Science and Policy Issues
Assessing the Quality of Medical Care
Life-Sustaining Technologies and the Elderly
Losing a Million Minds: Confronting the Tragedy of Alzheimer's Disease and Other Dementias
New Developments in Biotechnology
Infertility: Prevention and Treatment
Mapping the Human Genome
New Communications Technology: Implications for Privacy and Security
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Communications Systems for an Information Age
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FEBRUARY 1987